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VOLANTE

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Landscape change processes in case study areas (WP2)

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COOPERATION

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Executive summary

The VOLANTE Deliverable D2.3 presents the analysis of landscape change in selected study areas in Europe, as well as a description of the processes of landscape change. These study areas are the same as the study areas used for WP1 (which assesses the decision making in land use change).

The important processes of landscape change, intensification and extensification will affect landscape identity but also character and biodiversity. To mitigate the negative impacts of landscape change processes it is important to identify and determine the drivers of change, and adjust policies where necessary. This study aims to describe the changes occurring in the study areas and to identify these drivers of change.

Land use and land cover changes were assessed based on comparison of maps over a longer period (at least ten years). The time frame depends on the country and was therefore not the same for all study areas. For some countries maps for different years were available, sometimes more than 100 years old, but for comparison we used mostly the map around the establishment of the EU.

Not so much changes in cropping patterns were studied, but rather changes between land use classes, e.g. from agricultural use to nature, or from nature towards build-up area, and. Where possible also changes in landscape elements were assessed (hedgerows, ponds, terraces) but spatial data often lacked this detail. However, the more 'visual' aspect of landscape change is hard to assess with comparison of digital maps or landscape indices, this was addressed with a more quantitative approach.

In the study areas the overall changes are rather small: in most cases less than 10%, which is surprising considering the time period which spans often decades. Exceptions are Portofino (IT) and Reichraming (AT). Portofino has changed very much, but most changes took place in the natural area, and the changes are due to natural succession and probably also the occurrence of the frequent fires occurring in the area. The change for Reichraming (42%) is more related to the quality of the map data used, in this case the Global Land Cover map. Even in Stăncuţa and Răteşti (RO) where major political changes took place, overall land use change is still approximately 12%. We show in this study that agricultural expansion still continues, the productive land has on average increased by 4%! On the other hand, marginalisation of agriculture occurs in disadvantaged regions of Europe.

This also points to a more general problem encountered in this study, the quality of vegetation or land use mapping. The quality of the maps depends on the available map data and imagery, the method and detail of classification etcetera, which leads to differences in accuracy between the maps of case study areas. Maps which are available for all of Europe like the Global Land Cover Map or CORINE (CLC) are not detailed enough for studies at this scale. Also, this common approach based on the comparison of maps for different periods shows the differences in main land use categories, but fails to show the impact on landscape itself.

The assessment of land use change processes and the underlying drivers is very complex:

EU policy interacts with national and regional policies. The outcome is often not uni-directional: European policies sometimes result in change (e.g. as a result of infrastructure development), at the same time they can 'conserve' a status quo, inhibit changes (e.g. through subsidies). They may have counteracting or mutually amplifying effects on land use;

The observed changes are a result of already on-going processes which interact with a multitude of drivers. The strength of these drivers differ;

The local reality is probably very important in the arena of landscape change: the local economy, in combination with the environment and local conditions, will result in changes. Local culture is often overseen in this arena, but will affect land owners decisions, as well as the governance culture;

The drivers were assessed by the VOLANTE teams for the respective study areas. The processes observed in our case study areas are very much influenced by the 'large scale processes', drivers that operate at a European level. Even in the least accessible case study area European policy and globalisation have their impact on land use.

Environmental drivers seem less influential in the end than e.g. transport and infrastructure or environmental policies and legislation. Urbanisation and sprawl seems a driver for changes in other land uses, and is most frequently occurring driver for change in other sectors. On the other hand, globalisation and market forces also affect most land use types. Policy on the one hand and economy on the other may be dominant and opposing drivers in the landscape change processes. Land use zoning and protective designations is a strong driver for many more sectors than just protected areas, it also affects build up areas, grasslands and crops. Driving forces with less influence on other land uses are e.g. technology, climate change or energy policy.

The conclusions of this study are extrapolated into a number of preliminary policy recommendations.

1 Introduction

1.1 The European context of land use change

Sustainability of land use – one of the key issues of the VOLANTE project – is related to the provision of landscape functions and associated services 385 ha, see Costanza et al. (1997):

1. food, energy, housing and transport (economic land use functions / production functions),
2. abiotic and biotic resources (environmental land use functions / regulation and habitat functions) and
3. work, leisure and recreation, and identity (societal/cultural land use functions / information functions).

Land use change is one of the resultants of these functions, and continuously changing in response to environmental conditions, socioeconomic and cultural factors, technological changes and policies (Bürgi et al., 2004; Primdahl et al., 2013a; Primdahl et al., 2013b; Veldkamp and Lambin, 2001).

Major land use change processes

The intensification or extensification processes (Verburg, 2009; Vos and Klijn, 2000) affect landscape identity but also character and biodiversity (Stanners and Bourdeau, 1995; Stobbelaar and Pedroli, 2011). Agricultural intensification is defined here as higher levels of inputs and increased output (in quantity or value) of cultivated areas or reared products per unit area and time (Lambin et al., 2001). Agricultural expansion often compromises biodiversity, and leads to encroachment of natural areas (Brussaard et al., 2010). Land use intensification is an important pressure which affects negatively environmental quality and biodiversity (Petit and Elbersen, 2006). Environmental pressures like climate change and pollution add to this and lead to change of landscape character (Plieninger, 2006). Fragmentation as a result of transport infrastructure is another important change (Van Eetvelde and Antrop, 2009). To mitigate these negative impacts it is important to identify and determine the key elements of landscape change processes, and adjust policies where necessary (Plieninger et al., 2006). Also the type of farmers as well as the different socio-economic settings will define the outcome and may lead to different decisions regarding landscape management, and may thus have implications for these trajectories of landscape change (Kristensen et al., 2001; Primdahl et al., 2013b).

European research projects

In European studies such as Eururalis (Rienks et al., 2008) the aspect of globalisation is and will be increasingly important for future land use in Europe. In particular the demand for food and fuel and the global trade and liberalisation of trade will in the end affect farm income, farm structure and agricultural land abandonment. How EU policies on CAP and bioenergy respond to these processes, will largely define how the future landscape will be shaped (Rienks et al., 2008). However, this study already indicates that the role of farming in Europe is likely to decrease in the future, the economic significance of farming is declining, as does rural employment. Some scenario's predict large scale land abandonment: Eururalis predicts 10-12% abandonment of total agricultural land until 2030, other studies show similar tendencies. A consequence of the decrease of open farmland landscapes will be the loss of specific habitats and valuable landscapes. Also the environment will be affected, in particular quality and stability, nutrient status of the soils, erosion intensity, ecosystem production capacity, and biodiversity will be affected (Rienks et al., 2008).

Van Eupen et al. (2012) prepared within the FARO project a typology of European landscapes based on the environmental zone, the economic activity, and accessibility (Figure 1). These factors can be considered dominant drivers in multifunctional land use. The resulting typology is as follows: Peri-urban, Rural, and Deep Rural. Each 1 km2 of Europe was classified according to the nine or three rural classes.

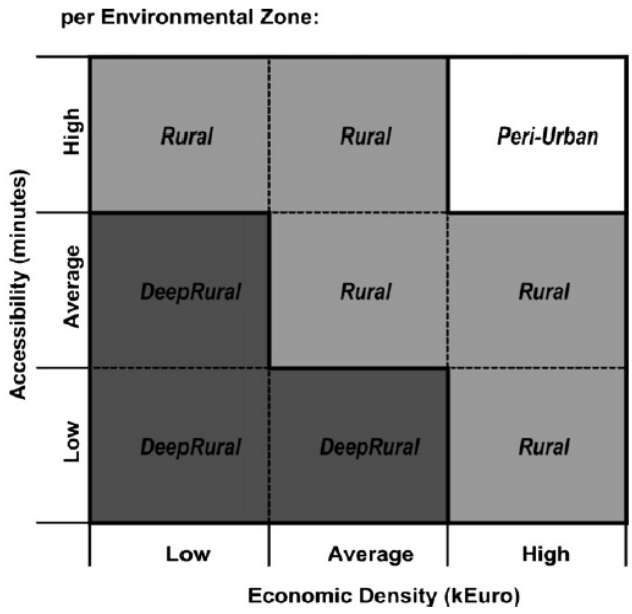

Figure 1: Rural typology based on Accessibility and Economic activity (Van Eupen et al., 2012)

Different environmental processes lead to larger vulnerability, i.e. the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. in the context of the EU Framework Five Project ATEAM the vulnerability concept was developed especially to integrate results from a broad range of models and scenarios and make predictions for future land use (Schröter et al., 2005). In total seven scenarios were evaluated, with different degrees of climate change. A common trend found was that agricultural land is declining all over Europe, as well as land use intensity, and urbanisation was increasing in all scenarios. These scenario's may have limitations, but most scenario's show the same tendency. The outcome may not differ, but spatial patterns in which e.g. urbanisation occur can vary a lot (Rounsevell et al., 2006). The governance aspect, the way how Europe develops its policies and how they are implemented, will define the land use pattern of tomorrow. In Work Package 4 of the VOLANTE project the long term changes in land use are studied in more detail, whereas the impact on Ecosystem Services are assessed in WP 8 (http://www.volante-project.eu/consortium/53.html).

Landscape and Land use change in Europe

Major land use changes in Europe, identified on the basis of Corine Land Cover, for the period of 1990-2000, were: urbanisation, intensification of agriculture, extensification, afforestation, deforestation, and construction of water bodies. The change observed was on average 2.5% (Feranec et al., 2010). However, the overall rate of change seems to have slowed down to 1.3 % for the period 2000-2006 (EEA, 2010). Major processes observed in this study from the EEA (2010) is the land specialisation, which is described as urbanisation, agricultural intensification and abandonment plus natural afforestation. It is expected that this trend will continue. The increase in artificial surface is the largest change with 3.4%. Where in the past this mainly comprised urbanisation, for the last period this is more attributed to economic development sites and infrastructure. This increase in artificial surface has exceeded the growth in agricultural land. The forest area increased slightly (0.1%). Arable land and permanent crops decreased by 0.2%, pastures and mosaics by 0.3%. The natural habitats and wetlands declined further, whereas artificial water bodies increased (EEA, 2010).

1.2 Objectives of this deliverable

The VOLANTE project mostly studies the land use change processes at European scale level. However, drivers of change operate differently at the local or regional level (Bürgi et al., 2004). The role of land owners and users can be more influential, but also local authorities will affect the outcome of the complex system of decision making regarding land use trajectories. Work package 2 therefore also studies the local processes, for which case study areas are selected to study land use changes and decision making regarding land use in detail (Cosor et al., 2012). Also specific attention is paid to the issue of policy and governance (Frederiksen and Vesterager, 2013).

This report presents an analysis of changing land use in six case study areas in different zones in Europe: Romania, Austria, Greece, Italy, the Netherlands and Denmark, against the background of a broader study of land use transitions in Europe (Rounsevell et al., 2012). Within the case study areas the changes in land use and landscape, as well as the underlying decisions are studied at regional level. The case study areas provide a kaleidoscope of landscapes in Europe and form an illustration of the change processes. Although the idiosyncratic nature of the areas does not easily permit generalizations, we presume the trends observed can be indicative and provide insight into landscape change at a regional and European scale. Based on the observed trends in land use change, the impact of land use transitions on the future landscape and landscape structure will be discussed.

The focal question for this Deliverable is therefore: What are the land use changes that occurred in the VOLANTE case study areas over the past decades? Which changes can be attributed to European policy, and in particular the CAP Environmental measures and the Habitats Directive? How do the changes in land use affect the landscape, and ultimately biodiversity?

Herewith, we focus on the visual aspects of land use change, i.e. not so much whether it changed from one arable crop to another, but rather change from forest towards permanent grassland or cropland towards forest. Besides the land cover aspects, we also compare other attributes of the landscape, e.g. scale of the land parcelling, as well as landscape elements such as single trees, ponds, hedges, tree rows, stone walls etcetera.

How can we detect changes in land use and landscape, and quantify them in our case study areas, based on a spatial (map) analysis? For the analyses we compared maps of different periods, to detect changes. Also landscape indicators have been selected which are suitable at national levels, and useful for different regions in Europe. The map quality and detail defines the suitability of these indicators. The indicators must be good and descriptive in different regions of Europe, and at different scales.

1.3 Set-up of the report

In Chapter 2 we present the case study areas that were analysed in WP1 and WP2 of the VOLANTE project. Also the indicators that were analysed, as well as available map data are presented. Chapter 3 presents the land cover changes in the case study areas. This is based on statistics for the land cover maps that have been compared, for different periods (which are in detail presented in Annex 1). The landscape change processes and land use intensity are described, as well as the drivers of land use change, and the period of change, as well as the impact of these changes on the landscape itself. This is followed by the discussion (Chapter 4) and conclusions and recommendations (Chapter 5).

2 Analysis approach

In this chapter the case study areas are presented (Par. 2.1), the analysis approach (Par. 2.2), the specific indicators that are relevant to describe land use change (Par. 2.3), and the available data – in particular maps, for the case study areas (Par. 2.4).

2.1 Case study areas

We selected 6 case study areas, in different regions and landscapes in Europe. The selection of sites was based on areas for which prior knowledge and research data regarding land use and policy impact was available. However, an extensive study of literature on land use change and policy (Cosor et al., 2012) revealed that such studies are rare. For that reason it was decided to study the case study areas which are also topic of research in work package 1, which studies processes of land use change at farm level. The 6 case study areas are: Roskilde (Denmark), Heerde (The Netherlands), Portofino (Italy), Lesvos (Greece), Reichraming (Austria) and Răteşti and Stăncuţa (Romania) (Figure 2).

The case study areas represent different landscape types in Europe. This is reflected in Table 1, which indicates the environmental zone and habitats which are present in the case study areas. The areas differ not only in environmental zone and dominant land use system, but also in the size of the case study area. The smallest area, Portofino, measures only 18 km2 whereas the largest area, Lesvos, measures more than 1080 km2. Further, the dominant land use type (and often farming types) are different: Forests in Reichraming, Olives in Lesvos, Macchia and olives in Portofino, Cropland in Roskilde, Stăncuţa & Răteşti, and grassland in Heerde.

Figure 2: Location of the 6 case study areas

Table 1: Land use types in the VOLANTE case study areas (Metzger & Bunce, unpubl.)

	Lesvos, GR	Reichra-ming, AT	Roskilde, DK	Heerde, NL	Portofino, IT	Stăncuţa & Răteşti, RO
Environmental Zone	Mediterr. South	Alpine South	Atlantic North	Atlantic Central	Mediterr. North	Continental
Size area (km2)	108	102	212	80	18	255 / 79
Urban sealed	x	x	x	x		x
Urban mixed	x	x	x	x	x	x
Urban recreation	x	x	x	x	x	x
Crops	x	x	x	x	x	x
Woody crops	x				x	
Waterways		x	x	x		x
Wetlands			x			x
Coastal	x				x	
Geomorphologic features	x				x	
Grasslands	x	x	x	x	x	x
Native grasslands	x	x			x	x
Heathland	x			x	x	
Scrub	x	x		x	x	x
Forest		x	x	x	x	x
Woody landscape elements	x		x	x	x	
Stone walls & terraces	x				x	

We can ordinate our study areas in the division of Van Eupen et al. (2012, fig. 1) as follows (Figure 3):

Accessibility \ Economic density			
	Rural	***Rural*** Răteşti	***Peri-urban*** Roskilde Portofino[1]
	Deep rural	***Rural*** Reichraming [2] Heerde [3]	***Rural*** Lesvos
	Deep rural Stăncuţa	***Deep rural*** Reichraming	***Rural***

Figure 3: Typology of the case study areas based on FARO (Van Eupen 2012)

[1] Although the local area surrounding Portofino case area is considered peri-urban (proximity to large town and highway), access to the case area is difficult, the Regional Park designation restricts agricultural activities and the area shares many characteristics with marginal agricultural areas (aging population, lack of investments, etc). For these reasons, we will consider the case area as marginal/deep rural, even if the FARO typology, which uses a coarser geographical resolution, designates it as peri-urban.

[2] Half of Reichraming has low, half has average accessibility to services.

[3] In Heerde the farming area has high economic density; the forested part has average economic density.

Based on this typology, the outstanding positions are taken by Stăncuţa, which is most rural, and Roskilde and Portofino which incorporate the most peri-urban patterns in land use. Lesvos would perhaps better fit with Heerde and Reichraming as rural, with average economic density, the high density could be due to Mytilini and the infrastructure along the coast, whereas the inland territories show much less development.

2.2 Method for landscape analysis

Processes of land use change differ in temporal and spatial scale. Trajectories of land use change may differ in regions in Europe. Land use and landscape data makes it possible to detect change over time, and to quantify these changes. However, maps alone may not be enough, secondary data may be required for interpretation of the results, e.g. existing literature and knowledgeable sources.

A spatially explicit temporal analysis was done to define the landscape changes in the case study areas over the past 40 years (since 1972, the establishment of the EEC). If no digital maps were available for the case study areas maps were prepared, with satellite imagery or aerial photographs. For each area the available maps therefore differed, although there is CORINE Land Cover CLC or Global Land Cover Data for each of the areas. In some cases a check has been done with regard to land parcelling, landscape elements, drainage system and other landscape features.

Time series for at least 2 periods were used. The first period for comparison should be after 1972, but preferably before 1992, since substantial impacts from the CAP date from 1992 onwards. However, a pragmatic choice was made based on availability of digital data for our case study areas. The land cover change was calculated in two different ways: as measure relative to the total size of the case study area, and as absolute measure, i.e. with regard to the first measurement (i.e. if urban area increases from 5% to 20 %, relative change is 15%, the absolute change is 300%)

Driving forces are important for the understanding of ecosystems and the forces that regulate the environment. Drivers of land use change are scale dependent, and sometimes spatially explicit (Lambin et al., 2001; Veldkamp and Lambin, 2001). They operate at spatial, temporal and institutional scales (Bürgi et al., 2004). They can be categorised as political, economic, cultural, technological and environmental (natural and spatial) forces (Hersperger, 2009), which may all operate at different levels. An example for driving forces at international level are the trade conditions, which affect national prices, whereas at the municipal level the financial strength of the municipality may be decisive in local infrastructure development: two economical drivers, which operate at different levels.

2.3 Indicators of landscape change

Indicators are a useful proxy to describe landscape change, based on physical characteristics of the landscape. The indicators may include land use and land cover (Benini et al., 2010; Plieninger, 2006), land use intensity (Roose and Sepp, 2010), landscape functioning (Levin and Jepsen, 2010; Van der Sluis et al., 2004), visual aspects of landscape (Levin, 2007; Stobbelaar and Pedroli, 2011), and biodiversity (Andersen, 2003; Honnay et al., 2003; Normander et al.). Moreover, the purpose of the landscape assessment should be guiding in the choice of indicators, and the landscape assessment approach (Wascher, 2004).

The following indicators are most relevant for the purpose of this deliverable:

- Land use and land use change

The most clear indicator of landscape change is land use, which can be quantified as (share of) total vegetation cover. In Chapter 3 we describe the land use changes, and the processes behind land use change, through the driving forces, and the period of change. A more extensive description, with all background data and tables is found in Annex 1 of the report.

- Landscape structure (forest, tree cover, build-up areas & farms, landscape diversity index, relief, openness, parcel size)
  The landscape structure refers to more visual aspects and qualities, which relate to: open or closed, vertical elements (buildings, treelines, single trees, forest) and relief. Some of these aspects can be measured, others can be complex where it relates to more subjective quality aspects.
  Landscape structure defines also the life support functions of the landscape, in particular biodiversity. It relates to landscape connectivity, habitat functions and potential to sustain wildlife populations (Van der Sluis et al., 2004). The change of landscape structure is discussed in par. 4.4. Most of these aspects can be defined by analysis of maps and, in some cases, remotely sensed data, varying from aerial photographs, Google maps, satellite imagery etcetera. Most of this work was done in a GIS environment, with ArcGis (ESRI, 2011) and available maps.
- With Fragstats (Mcgarigal et al., 2002) we calculated landscape indices. The following indices were prepared:
  - TA=Total area
  - NP=Number of Patches
  - PD=Patch density
  - TE=Total edge
  - ED=Edge density
  - AREA_MN=Patch area (mean)
  - PARA_MN= Shape Perimeter-area ration (Mean)
  - CONTAG = Contagion (aggregation)
  - SHDI=Shannon's Diversity Index
  - SHEI=Shannon's Evenness Index

Drivers of change were identified by experts involved in the data collection for WP2 and the farmers interviews (WP1). The assessment was supported by the background knowledge from the interviews, and, where possible, use was made of literature, workshop data and other expert knowledge.

2.4 Available map data

Data for a comparison of land cover change is derived from different sources. For a comparison of all areas, the same type of data is required for all case study areas. CORINE land cover data is often used, however, CORINE land cover maps are of limited use for mapping land use change at this scale level due to their relatively coarse scale and large minimum mapping unit (25 ha). Therefore Global Land cover data seems better for the purpose of comparing the case study areas. The ESA Global Land Cover map legend was developed using the United Nation Food and Agriculture Organisation's (FAO) Land Cover Classification System (LCCS). The map was generated using Envisat's imagery from the ENVISAT satellite, to provide a spatial resolution of 300 m. Data were collected between December 2004 and June 2006. A second map was prepared for 2009 by JRC in ISPRA with a slightly different classification algorithm.

For a detailed landscape change assessment, an inventory was done of locally available GIS data, either from classified remote sensing imagery, aerial photographs, or topographical maps, available in digital format. Table

2 provides an overview of the available digital maps for the case study areas, indicating for which year maps are available.

Table 2: Digital maps available for the project areas

Project area	Roskilde, DK	Reichraming, AT	Răteşti, RO	Stăncuţa, RO	Lesvos, GR.	Heerde, NL	Portofino, IT
Global Land Cover	for all areas, 2004-2006, 2009						
LU-Maps based on RS/ Aerial photo	LU/LC 1990 2011 agricultural LU Lakes 1950 Forest		1979/80 2003	1979/80 2003	1960 1981 1990 2004 Roads Rivers	LU/LC 1996-2008; Historic LU 1900/1970	1936 1954 1971 1991 2000
N2000 + protect	yes	no	no	yes	yes	yes	yes
Landscape elements	hedgerows 2001					hedges, ponds 2012, Agri-env. schemes 2011	Terraces

Land use data originates from a variety of sources and is available at different spatial scales and varying degrees of detail. In most cases primary sources were used (satellite or aerial photos) to produce original maps while in other cases, secondary sources (topographical maps) were used.

Lesvos (Gr): Maps for Lesvos were prepared based on aerial photography for the years 1960, 1981, 1990 and 2004, by Giorgios Tataris, GIS specialist of the Aegean University. This land cover map was prepared as a geodatabase, with the urban areas for this same period, and additional data (roads, rivers, airport). Ground truthing was done in specific areas, to check on differences between the periods of mapping and accuracy of the classification.

Reichraming (Au): Within the project there is no GIS data or statistical data readily available, no map has been prepared based on remote sensing imagery thus far. The costs for statistical data at municipality level are prohibitive. Therefore the Global Land Cover map data is used as only source.

Roskilde (Dk): Digital land cover maps are based on land use in 2002, based on farm registration data collated at the municipality level, as well as land owners information. The LU/LC-classification was prepared for the emission inventories. The maps are in raster format with a resolution of 25x25 meters (Gregor Levin, in prep.). It is most detailed concerning agricultural land use (crop type) whereas other types of land cover are described in less detail (e.g. there is only one category of forest). Also digital maps with the designated areas are available (Natura 2000, water protection areas, etcetera). The scale of mapping varies from 1:10.000 to 1:50.000.

Heerde (Nl): Aerial photographs are available, as well as topographical maps scale 1:10.000 for the periods from 1970, 1980, 1990, 2000 and 2009. These maps lack detail in land cover. The historical land cover maps, HGN, are 25m grids based on old topographical maps. HGN is at scale 1:50,000 (1:75,000 for 1900) and based on old topographical maps, which date back to 1900, 1960, 1970, 1980, and 1990 (Knol et al., 2004). The maps are in Raster format. More detailed land cover maps have been prepared based on LGN, satellite imagery (Hazeu, 2006). These maps are regularly updated, and are being used for the farm registration and subsidies. The methodology changed slightly over time, therefore the LGN1, 2 and 3 differ from the LGN 3+, 4, 5 and 6. LGN 3+ is based on satellite imagery from 1995-1997, LGN 6 is based on 2007-2008. The latter map differs slightly from its predecessors and makes it therefore not entirely comparable.

Portofino (It): Both colour composite images and false colour images are available. Land use maps are based on historical orthophoto's and were prepared for: 1936, 1954, 1974, 1991 and 2000 (Pedroli et al., 2013). Besides, extensive historical research was done, with (detailed) qualitative descriptions from the Middle Ages onward. The landscape change was studied in detail, i.e. changes in attributes like vegetation, farming area, historical terraces, parcel size, drainage pattern etcetera (Pedroli et al., 2013).

Răteşti (Ro): A topographic map 1:25,000 (1979-1980) and aerial photos 1:5,000 (2003) were digitised for the purpose of this analysis. Census data about land use is available for the 1990-2010 period. In **Stăncuţa** land cover and protected areas information, derived from topographic maps 1:25,000 (1979-1980) and aerial photos at scale 1:5,000 (2003), which has been digitised. At the acquisition time of the aerial photography the Danube River experienced high flood levels so the area under the natural flooding regime (the Natural Park) was less detailed. Ground truthing for the Small Island of Braila Natural Park was done in August 2013. Land use data is based on census data (1990 – 2010). The 1980 map 1:25,000 is the latest available at this scale, all the subsequent topographic maps are at larger scale and are based on the 1980 map.

3 Landscape change

3.1 Introduction

In this chapter a comparison is presented of the most important land cover change in the case study areas. This chapter 3 contains only the map of land use changes, as well as the land conversion that took place in the area. In par. 3.3 the drivers of land use change are discussed, 3.4 discusses landscape scale and visual impacts of landscape change. The detailed description of all areas is found in Annex 1, which includes the tables and land use statistics, but also the general land use map and detailed maps.

3.2 Land cover change in the case study areas

3.1.1 Lesvos

The study area lies on the Eastern tip of Lesvos island, around Mytilini city. The area measures 10,870 ha. Most of the area in Lesvos case study area is farmland, of which most (some 50%) is olive groves. Olive growing has a long tradition on the island, and dates back for centuries (Kizos and Koulouri, 2006; Petanidou et al., 2008) In addition there is pine forest, the forest of Kratigos-Amali. However, due to fires the forests have been severely damaged, in particular the fire of 2006 has been disastrous. Mainstay for the people is olive oil production, which is partly for the market, partly for own consumption. Tourism has been gradually increasing, it is mostly small-scale tourism, dispersed over the island with development of holiday houses. There are pockets of tourism development, settlements attracting small hotels and restaurants.

Lesvos's agricultural landscape zones can be roughly described by grazing lands, olive groves, and an intermediate zone (Kizos & Koulouri, 2006). The grazing lands consists mainly of barren lands (>50% of the area) in which soils with limited nutrient availability are deposited on recent lava and tuff (Higgins and Higgins, 1996). The olives groves have a land use primarily consisting of olives and pine forests. The intermediate zone includes elements of both other zones (grazing lands, arable land, olives and pine or oak forests).

We compared the statistics for the different years, from 1960, 1981, 1990 and 2004. The research area is defined by the communities that were included in the farmers survey (Kristensen et al., 2012). Most important change in land use between 1981 and 2004 is the gradual decrease in olive groves (- 2.1%) and an increase in build-up area (relative increase + 2.1 %, or an absolute increase by 50%) (See for detailed figures Annex 1). The decrease in olive groves is a process since 1960, however, as Kizos and Koulouri (2006) show olives were typically a crop which changed the diverse farming system in a monoculture one century ago. It is a result of the low prices for olive oil on the international market, which makes olive growing unattractive for economic reasons. Even if there are niches such as organic products, local players are not able to exploit them, as they sell in bulk and therefore are unable to fully valorise their product (with some small scale exceptions). Also, the growing of olives is labour intensive, and with an aging population this is more and more difficult. This results in people that resettle in villages or cities, abandoning their olive groves. In some areas (e.g. Moria) people choose alternative crops, and farmers also turn to biological olive oil production.

EU policy has mostly impact on the landscape through rural development programs involving agro-tourism and other types of alternative tourism, road building, and development of infrastructures (e.g. Leader, Rural Integrated Programs). Such EU policies have direct or indirect strong impact on landscape (P. Baggelis, pers. com). In Lesvos landscape change as a result of EU policy is slow. Policies also may aim to preserve the landscape.

If we take a longer time perspective we observe more conversion of olive groves and urban expansion (the urban area has doubled since 1960). Urban settlement expands as a result of development and expansion of

villages, and to a smaller extent expansion of Mytilini. However, there was also expansion of an industrial site along the road Mytilini-Kalloni, from Alifanta to Larsos, for wholesale shops and industrial production, which increases the build-up area (T.S. Terkenli, pers. com). The urbanisation process was strongest from 1960 to 1980. After 1990 the urban settlement boundary on Lesvos was extended. There has been a small increase of forest land, as a result of subsidies for reforestation. Forest areas have increased, but part of the forest was destroyed as a result of forest fires after 2004.

All in all the changes are rather small, and don't exceed 2.1 % for any one land use class over a period of 25 years, which is a bit surprising considering the long time period.

The Global land cover data for 2005 and 2009 is quite a contrast with the land use maps of the area. It may show that the GLC classification of olive groves is highly diverse: 75% of the olive groves are classified in GLC as area with 'sparse vegetation' and 'closed to open shrub land'. These results are therefore not reliable enough for comparison.

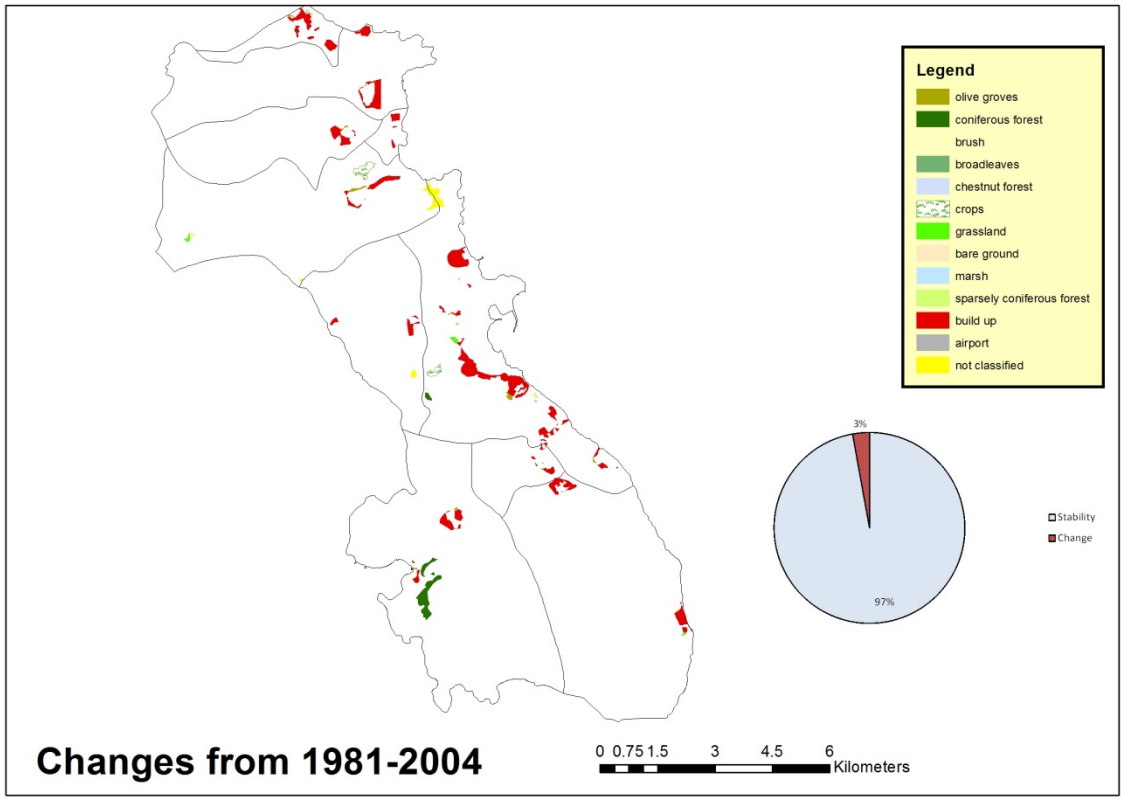

Figure 4: Land use change and stability for Lesvos area

Overall land use change is limited: some 3% is changed, which means that 97% was stable in the period from 1981 to 2004 (Figure 4). Most change occurs on the Eastern part of the mountain range, along the main axis of development (the main road from the airport towards Mytilini, and further north. Most striking change is the expansion of build-up area. This happens mostly in a concentrated pattern, often adjoining existing town and villages. It indicates that it is mostly the urban processes which drive changes in the countryside. To a limited extent expansion of forest took place.

Most important conversion process taking place is from olive groves into build-up area: in total 181 ha (Table 36). Olive groves were also converted into cropland and coniferous forest (31 ha). Also some 27 ha. of cropland converted into build-up areas. That part is 'not classified' is a result of not entirely overlapping maps.

3.1.2 Reichraming

Reichraming is located in the province of Upper Austria, the Eisenwurzen area. In the past there has been much mining and metallurgy, but most mines have been abandoned or relocated outside the area. The Eisenwurzen area has marginal agricultural productivity. The forests are encroaching as a result of declining agriculture (Kristensen et al., 2012).The area is dominated by forest which covers almost 80%, in particular in higher regions. It is mostly coniferous forest and mixed forest. Agriculture is mostly done on smaller farms, and the meadows are situated in the valleys (mostly in the North) and higher up in the Alps. Most of the 60 farmers raise cattle and produce milk. High nature value areas are present. The case study area measures some 100 km^2 (Gaube et al., 2009).

The only available land cover maps are the Global land cover maps for 2005 and 2009. Almost 85% of the area is forested, the remainder mostly being cropland (2009). The observed changes showed mostly a change in mosaic vegetation types, which may therefore not be indicative for the change processes in the area: these land cover types have rather similar patterns at this scale, an explanation may be that in fact overall land use change was limited. The most visible trend is that small farms give up farming or become part time farms. The bigger farms keep on growing, which is a restructuring process which goes on. Although intensification is difficult, farms still do intensify. The main aim of intensification is to reduce the work load, and in doing so making farming more attractive for younger generations (Kristensen et al. 2013). Part time farming is also more attractive for succession on the farm. New, less labour intensive farming types are e.g. rearing of sheep, horses, and game animals like deer.

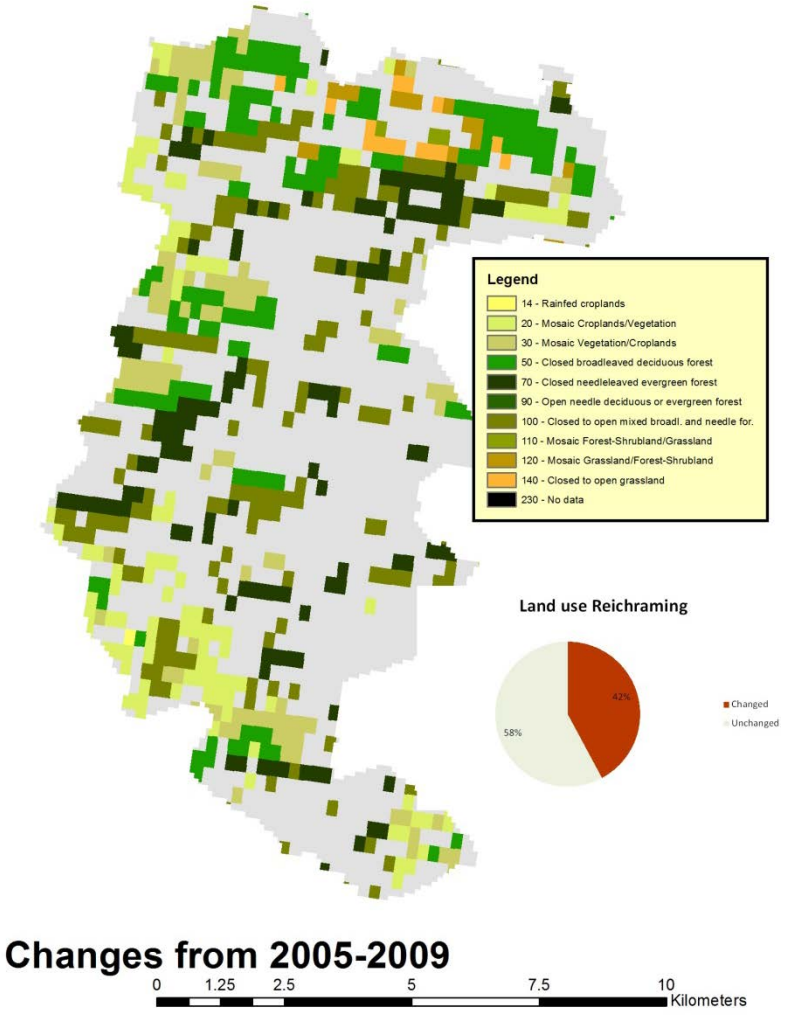

Figure 5: Land use change and stability for Reichraming area

Much of the vegetation changed (Figure 5) over such a short period of only four years' time: 42% ! As mentioned above, this is probably a result of the classification algorith, in relation with the different classes which are identified, which result in complexes of vegetation types.

'Cropland' as well as 'mosaic crops/vegetation have declined rapidly, most turned into 'closed broadleaved forest' (Table 37). Other observed changes are most likely a result of classification differences over the years.

3.1.3 Roskilde

Roskilde municipality measures some 212 km2. Most land use in this case study area is agricultural, predominantly crop farming (61%), but also housing and settlements put a large claim on the land (25%). There is a strong urban pressure on this area from nearby Copenhagen (35 km distance), which leads to conversion of land and farms for non-agricultural purposes (Kristensen et al., 2012).

The Land Use/Land Cover (LU/LC) map was analysed for the period 1990-2011 (G. Levin, pers. comm). The analysis of land use change during 20 years shows a decrease in cropland by -3%. There is also a slight increase in forest cover, and a decrease in grassland. This decline of farmland is probably a result of an increase in settlements (+2%).

The forest maps for 1950 showed that at that time 238 ha of forest existed (Table 12). In 1990 this area had increased to 723 ha, over the whole period to 2011 the total area has almost quadrupled. In 1950 rural and urban settlements totalled 1128 ha. Also the total built-up area has quadrupled. Lakes measured at 1950 only 250 ha and wetland 1295 ha (Annex 1). In particular wetlands have declined, nowadays they measure 473 ha. This is probably a result of land drainage for agriculture. Hedgerows form quite a dense network all over the county with a total length of 331 km (for more than 2200 elements).

The decrease of grassland (relative change -0,8%) is related to the reduction in livestock numbers and dairy cattle over the past 50 years. Farms were converted to hobby farms and part time farms. An opposite trend however is driven by 'horsification', the demand for grazing land and stables for horses, as well as the agri-environmental schemes for grassland management. Cropland decreased (-2,8%), probably as a result of expansion of settlements, but also gravel excavation and increased forest areas. The Gundsømagle recreational forest was planted in 2001, by 2009 there was some 106 ha. The increase in settlements, both rural and urban, is a bit inflated because cottage areas may be included in the mapping of rural areas. The agri-environmental schemes not only increased grasslands, but also wetlands have increased. Some farmers may have stopped draining their land due to the high costs involved.

The Global land cover data (Annex 1) show a decrease in sparse vegetation (-11.6%) and 'closed- to open grassland or forest on regularly flooded' areas' (-7.9%). The latter may be an artefact: although the area is low-lying it is doubtful that it is actually flooded. Further the comparison of GLC shows an increase in artificial surface (+3.8%).

Overall land cover change is some 5%, whereas 95% remained stable in the period from 1990-2011 (Figure 6). It is mostly urban expansion, or expansion of built-up areas, which occurs in particular around Roskilde city, and seems to decrease with the distance from town. Cropland decreases in this area, conversion of land into forest takes place in the areas at some distance from Roskilde.

The land conversion that took place is mostly cropland that was converted to settlements (385 ha, see Table 38). Some forest was converted into lakes, grassland, wetland and crops, but a large area of cropland (333 ha) was converted into forest which results in an increase of total forest area. The decrease in cropland is, besides conversion to settlements and forest also as result of conversion into wetland (68 ha).

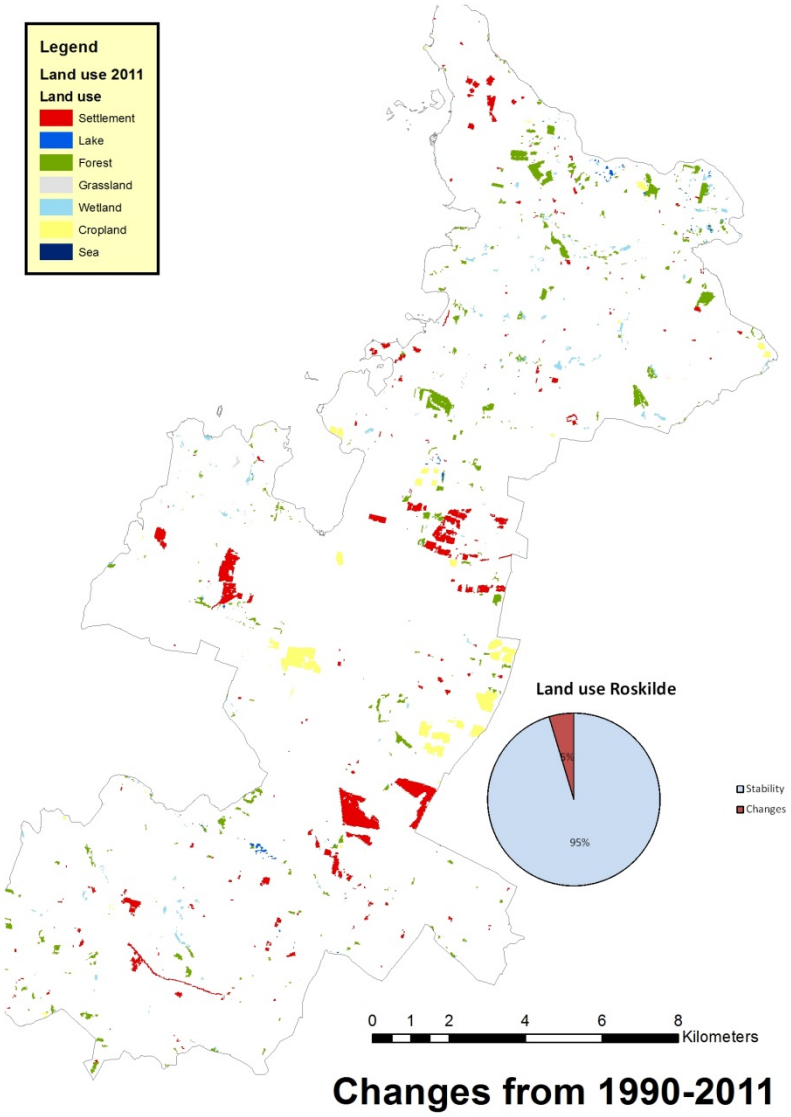

Figure 6: Land use change and stability for Roskilde area (Source: G. Levin, unpubl.)

3.1.4 Heerde

The Heerde municipality is located in the East of the Netherland and is situated along the northern part of the IJssel Valley. Its area encompasses approximately 8000 ha. The municipality can be subdivided in to three main landscape zones. West of Heerde is the largest forest area of the Netherlands, the Veluwe. Tourism and forestry are the main functions of this zone. Neighbouring this protected forest landscape is a transition zone where most settlement and infrastructure is found. This area is dominated by residential areas, infrastructure and service industries. East of the main settlements is the IJssel river, with adjoining floodplains and the traditional riverine landscape. Most land here is privately owned and used for agriculture.

There is increasing pressure from urban centres and tourism on the traditional land use lay-out. Like elsewhere in the Netherlands, rationalization and intensification of agriculture during the 20th century resulted in disappearance of hedgerows and shrubs, land consolidation of traditional fine-mazed agricultural parcels, scaling-up of farm activities and reclamation of floodplains. Partly this intensification is still ongoing as the number of farms has decreased. Fewer farms are now cultivating an agricultural area that has subsided only slightly. Furthermore, new functions develop for flood plains which have become important for water retention and climate-proofing of the region.

The LGN Land cover maps were compared, a land cover map based on a combination of satellite imagery and farming statistics. Most striking is the decline in grassland (-2.6%), and a slight increase in crops (+1.2%). Otherwise there is limited change in land use: this probably has to do with the shorter time frame. A comparison of the historical land use maps (Knol et al., 2004) show an increase of cropland (2.5%), and a decrease in meadows (-2.3%). The large changes occurred at the first half of the 20th century, in particular a decrease of heathers and moors, which were planted with forests for production of timber for the mines, but also as reclamation of ‘useless’ commons. Natural areas were converted into farmland, and cropland gave way to grassland and built-up areas.

A decline of cropland from 1900 until 1990 and a small increase in grassland resulted in a 2% decrease of productive area. Heathers that were converted into forests (for mining industry) at the beginning of the 20th century, and housing and other infrastructure increased as well.

The Global land cover data show a decrease in closed/open grassland (-13%), and sparse vegetation (-5%). At the same time, there is an increase of closed mosaic of grass and forest (+9%), closed broadleaved forest (+7%) and mixed forest (+6%). This may illustrate the process of more residential use of farming areas, with more planting of trees, and expansion of gardens at the detriment of the open meadow landscape.

Some 8% of change occurred between 1995 and 2004, some 92% was stable (Figure 7). Changes occur in all areas west of the Veluwe, outside the Natura2000 area. In particular around the settlements and along the road (running roughly NE-SW), and in the large scale farming zone along the river, in the south-east. Changes are very diverse, but mostly towards grassland or crops. Expansion of built-up area is not so apparent.

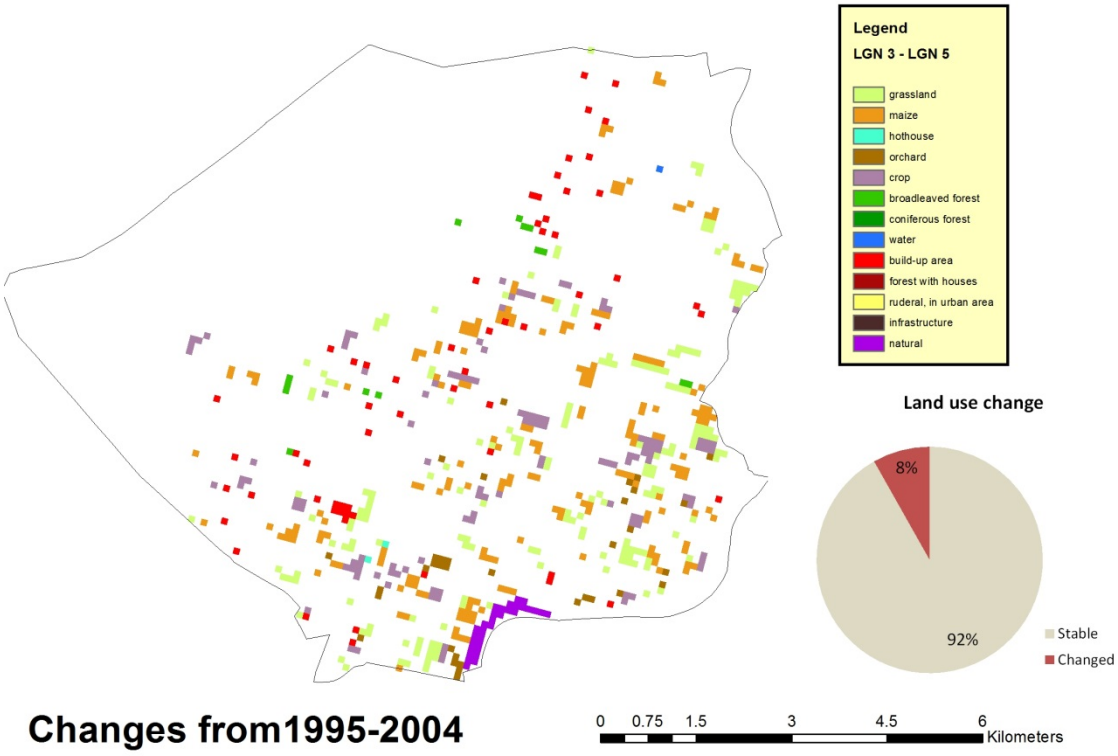

Figure 7: Land use change and stability for Heerde area

3.1.5 Portofino

Portofino is located in the “Mediterranean north” region, near Genova. The area is the smallest of all case study areas, and measures some 18 km2. The peninsula is an iconic Mediterranean landscape on the Italian Riviera, with steep rock cliffs over the Tyrrhenian Sea on the south side and deciduous forests on the north. On the east slopes small scale terraced agriculture has transformed in gardens for semi-residential housing, at the foot slopes culminating in the famous picturesque small natural harbour of Portofino. Since the peninsula was declared a nature reserve in the 1930s, it was protected to a considerable extent from mass tourist exploitation. However, the current Regional Park of the Monte di Portofino is subject to strong pressures of tourism and urban areas, and is at risk of substantial loss of its traditional values of outstanding natural beauty and cultural heritage. This problem is emblematic for large parts of the Mediterranean, and asks for a comprehensive approach to land use management.

The decline of farming is the most dominant process; it is the trend over most of the past century to date. Overall, agricultural land has reduced significantly with less than 400 ha. nowadays. From 1974 to 2000 we observe a decrease of agricultural land (-4.9%, calculated towards total land use), abandoned land doubled (+3.6%) and a slight increase in built-up areas (+0.9%) (Table 18).

The Global land cover data is less suitable for this analysis, since Portofino is one of the smaller areas, and the results are therefore much influenced by the grid cell size. One cell in GLC measures some 6 ha, which means that all of Portofino is some 30 grid cells. Relative small changes are quite considerable when expressed as %.

The productive area declined by -9% (even with ‘open area’ included, which can be gardens, but also open, rocky natural areas). This can mostly be attributed to change in total forest and macchia (shrubland).

Over the past 80 years more than half of the territory changed in Portofino. A strong contraction of farmland occurred from 1936 onwards (Table 19, Figure 8). Since 1974 34% changed: a large proportion of change has to do with natural succession, the change from e.g. macchia towards forest, but the large territory that changed in the western part of the area was also ‘open’, grassland in 1974, and is now mostly covered. North of Portofino olive yards have expanded as well.

The conversion of land is in particular in between agricultural crops. The classification differed over the years, which makes it hard to identify the changes in this (Table 40). Olive yards converted into ‘abandoned’ farmland, but also some was lost to built-up area and infrastructure. Some 56 ha. of macchia developed into forest, however, 206 ha. was classified as grassland, which may be due to fires which destroyed the macchia and gave an appearance of open grassland.

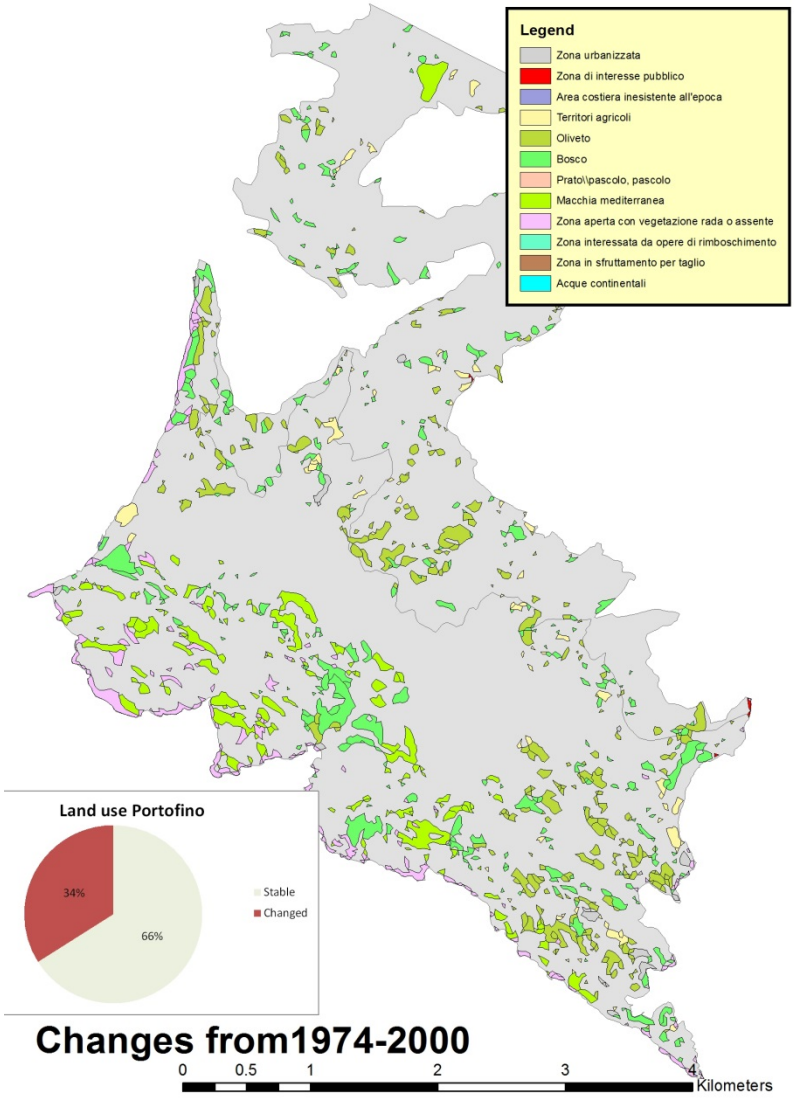

Figure 8: Land use change and stability for Portofino area

3.1.6 Răteşti and Stăncuţa

Romania has two case study areas: Stăncuţa and Răteşti municipalities, representative of the rural South-East part of Romania. Stăncuţa is situated in the Danube floodplains and measuring some 255 km2, Răteşti is situated in the south part of Arges county, in the Romanian plain and measures some 79 km2. The two areas have in common the agricultural policies in the Romanian Socialist Republic: before these 1989 were focused on gaining more land for crop production by conversion of natural and semi-natural areas into mono-functional agro-ecosystems (Vadineanu, 2004). After the revolution in 1989 this changed.

Răteşti

Răteşti municipality is an administration consisting of 7 villages, with a population of 3300 people. Land is use is predominantly agricultural, with over 80% of the area used for cereal and vegetable crops. There are still some cultivated pastures for small animal production, as over the years the stocking rate decreased. Forest cover is about 8% of the area.

The changes of land cover are not that large, considering the long period of 23 years, and the enormous political changes that took place in the area. A slight increase is observed of cropland (+4.3%) and built-up areas (+2.2) on the account of meadows and pastures (-7.2%) (Annex 1). Farm statistical data showed that the 570 hectares of pastures were transformed in 2001-2002. Productive land decreased by -4% for the period of 1980-2003 (Table 23), whereby orchards and grassland almost entirely disappeared. Forest and housing and infrastructure increased by almost 50%. Only limited changes are observed for Global Land cover: sparse vegetation decreases (-7%) towards mosaic vegetation and crops (+4%). It seems therefore that abandoned land is cultivated again.

The changes occurred mainly in the structure and management of the agricultural ecosystems due to the change of ownership of the land after 1990, when large state owned farms were replaced by small subsistence farms. There was an increase in fragmentation of agricultural land by 2005 (Kuemmerle et al. 2009), but this had no measurable effect on land abandonment in the lowlands of Arges (Müller et al. 2009). Since the beginning of 1990 the area of forest vegetation increased by 161 hectares. In 2009 a mineral aggregate holding (ballast) was established over an area of 370 ha on the Arges river shore.

A study of Arges county from 1990 to 2005 showed that cropland declined by -7.5% (of the study area), mostly in the period from 1990-1995 (Kuemmerle et al., 2009). Grassland increased according this same source by almost 16%. The largest increase occurred also in the initial period after the political changes. The forest area remained stable in this period. The landscape pattern changed as a result of the cropland-grassland conversion in this period, the parcels increased much in size. However, as Kuemmerle et al. (2009) explains, in the lowland part where Răteşti is situated the situation is different from the northern mountainous and hilly area. Most cropland abandonment took place in the hilly zone and the highest rates in the mountainous north. The plain areas in the south possess more suitable natural conditions and better market access, both of which have benefited the development of profitable farming" (Müller et al., 2009).

The total change observed between 1980 and 2003 was some 13%, so 87% remained stable over this period. Most change involved change into cropland, which involved large extended fields, mostly along the river from NW-to SE. Some forest was planted, and a limited expansion of grassland took place. Almost no change occurred towards built-up area.

Land conversion that took place is in particular the conversion of cropland into built-up area, in this way 121 ha. was lost (Table 41). However, all together 350 ha. of cropland was converted into infrastructure, forest areas and permanent grassland. Permanent grassland were to a large extent converted into cropland (576ha). Also permanent crops were not so permanent, and almost disappeared in the observed period.

An inventory was done of landscape features, and in total 360 trees were counted (2003), 870 shrubs and in total more than 16 km of treelines (in total 122 elements). The field check in 2013 revealed that it remained almost the same (pers. comm. M. Snoeijer).

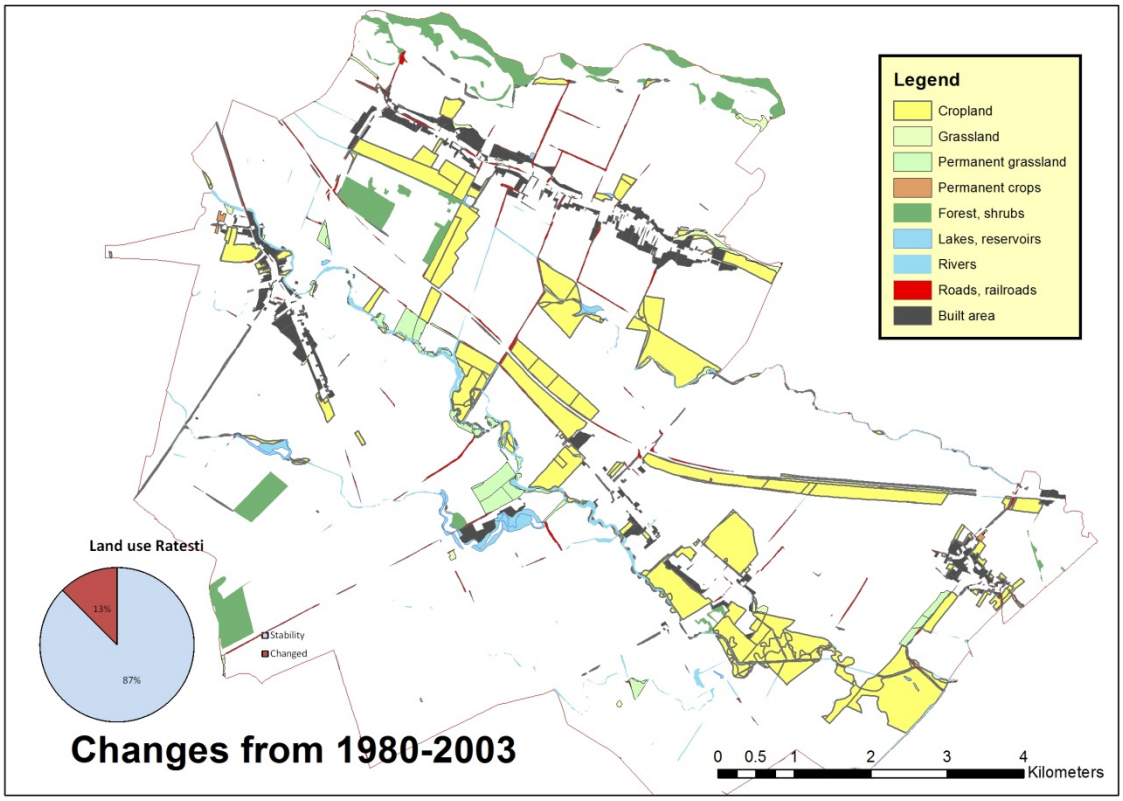

Figure 9: Land use change and stability for Răteşti area

Stăncuţa

In Stăncuţa dominant land use is arable land (52%), forest (30%) and rivers (11%). Also for Stăncuţa the land use changes are relative small, considering the enormous political changes (Annex 1). There is an increase in rivers (+2.7%), which can be explained by the overrepresentation of Danube River due to high water level at the time of acquisition of the aerial photos. Meadows and pastures decreased by -1.8%). Former rice fields were abandoned, and developed into meadows.

Changes for Global land cover data are in particular in areas with Mosaic vegetation/crops (+12%) towards sparse vegetation (-15%). This is most likely the result of reclamation of formerly abandoned (or not cultivated) land.

We compared total productive land for the period of 1980-2003, productive land decreased from 57 to 43.5% as a result of an increase of forest area and river. Also housing and infrastructure increased in this period.

Land use changes do not occur all over the area but seem to concentrate mostly near settlements in the centre and west (Figure 10). In total 11% of the land use changed between 1980 and 2003, while 89% was stable.

Some large arable fields were established, and along the Danube river some forests and few grasslands in the west.

Land conversion mostly took place from cropland towards permanent grassland (41 ha) and vineyards (88 ha) (Table 42). The class 'blank' has to do with not entirely overlapping maps, where comparison is not possible. The largest land cover change from rivers towards other land use (forest, 345 ha, cropland 555 ha) is a result of the different level of flood between the two assessed periods. Cropland increased as a result of conversion of permanent grassland (95 ha) and forest (75 ha). Conversion of built area into grassland, or infrastructure into rivers or cropland, is probably a result of inaccuracies in the mapping or classification.

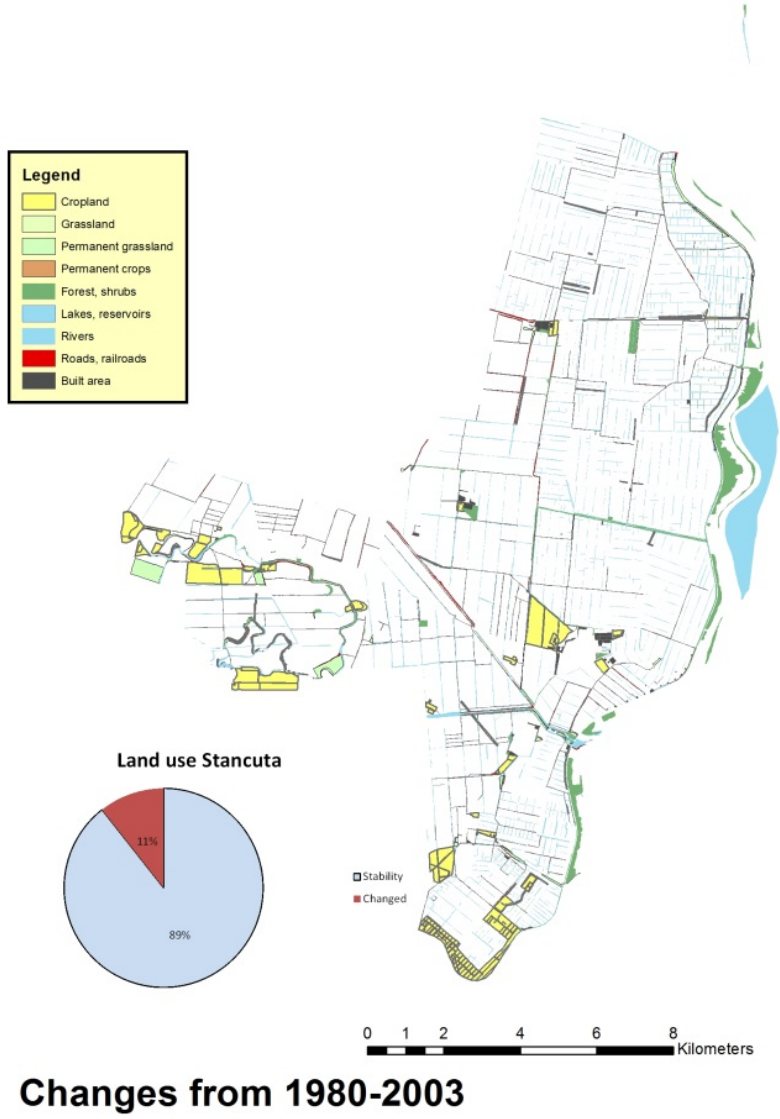

Figure 10: Land use change and stability for Stăncuţa area

3.3 Drivers of land use change

We focus at driving forces and their impact on landscape change in Europe. By ranking the drivers of change, insight is gained in the relative importance of different drivers and regional variation in landscape change processes (Soler et al., 2011). Its importance lies in the possibility to define how important political drivers are in comparison with e.g. environmental and economic drivers of change (Hersperger and Bürgi, 2010).

The drivers of change (Table 3) were identified by experts involved in the case study areas that did the farmers interviews (WP1) and were involved in assessments for WP2. The assessment was supported by the background knowledge from the interviews, and, where possible, use was made of literature and other experts. In the text box below the table a description is given of the processes which can be decisive in the landscape processes. Table 3 shows that drivers of change are many, affecting a wide range of land uses.

Major drivers of change

In general drivers grouped under 'transport and infrastructure', Economy and market' and 'Environmental policies and legislation' are most often mentioned as important. Striking is that environmental drivers seem less influential, e.g. a driver like climate change is only mentioned for a few areas, perhaps the impact of climate change is not felt yet, or not recognized thus far.

Spatial planning

Also 'Land use zoning' and 'protective designation' have impact on almost all land use types, not just protected areas: they also affect build up areas, grasslands and crops; planning and zonation seem to be powerful and effective instruments in all areas. In Denmark the zonation into rural and urban area (and in some cases summer cottage area) has had a major stabilizing effect on unregulated urban sprawl. Without the zonation, most likely more would have been converted to urban land use, resulting in a more dense urban expansion rather than urban sprawl. In Lesvos, however, the role of zoning has been ambiguous. The extension of urban zones has led to a spread of housing into the countryside, including houses and cottages for tourism. In Portofino there is strict control within the protected areas of the park, here it is mostly renovation of old farm and peasant structures. The newcomers sometimes convert to former gardening and extensive land use, in other cases a kind of alienation takes place, with new villas, neatly trimmed irrigated lawns and gardens planted with exotic species in the setting of an –otherwise- rural landscape.

Economy and market

'Globalisation' and 'market forces' are often mentioned drivers most land use types in all areas, including the areas classified as 'deep rural' and 'rural' (Figure 3, Faro typology). Globalisation reaches all areas in Europe, how remote they are. In particular the EU-market, the tariffs and prices for crops affect the farming sector, in all countries. In particular the productive land use is affected, but through increased income for local communities, and increased transport and access, urban expansion and build-up areas are also driven by the economy.

RDP-schemes and policies

Agri-Environmental schemes have been very instrumental in most countries for conserving High Nature Value farming areas and agro-biodiversity. Grassland management schemes constitute one of the most important schemes in e.g. the Netherlands and Denmark under the RDP. The CAP and other specific schemes and policies have resulted in establishment of perennial energy crops, as well as organic fruit orchards.

Protective designation

The N2000 designation is a powerful instrument, which affects many land uses, not only forests and wetlands but also crops, grassland and build-up areas. In some countries like Denmark permanent grassland is a protected category. In that case it is very difficult to convert this grassland to other use. Also many wetlands are protected, e.g. in Denmark bogs measuring > 0.25 ha are protected. In Heerde area all land along the river IJssel, as well as all of the Hoge Veluwe is protected under N2000. Also some "wet grasslands" or coastal meadows will probably resort into the wetland category. Lands which received a protective designation often benefit from AES-schemes, Life program etcetera.

Urbanisation and urban sprawl

'Urbanisation and sprawl' seems a driver for changes in other land uses than just build-up area, and is most frequently occurring driver with widespread impact on rural areas. This driver is in particular important (as may be expected) in Roskilde, Heerde, and Lesvos, but also in Răteşti.

Policy on the one hand and economy and urban sprawl on the other may be dominant and opposing drivers in landscape change processes everywhere. Where zoning and policy may guide spatial developments, the market and urban sprawl can still lead to development processes which are contradictory to the spatial zoning plans.

Agro-technology and farm mechanization

Agro-technology is an important driver in cropland and grassland, and in some cases wetlands, in all case study areas. The introduction of new and larger machines may render some small areas uncultivable (usually due to drainage problems) and farmers may decide to change land use from crops to grassland, wetland, afforestation, and probably also energy crops. New technologies have also led to drainage of former wetlands and marshlands. Agro-technology is less effective in some marginal farming areas like Portofino, although mechanization has come a long way in e.g. vineyards, with smaller motorized equipment that can manoeuvre on narrow terraces.

Forest areas

In all case study areas the total forest area has increased. Forests are affected by many different drivers. Depending on the economic conditions for agriculture, as well as the flexibility in land use planning, land owners may decide to plant forest instead of crops. In countries like Denmark some farmers switch to forestry, although in the Netherlands this rarely happens since it decreases the value of the land. The afforestation scheme in Denmark (1991) is an important driver behind the farmland afforestation in Denmark and in Roskilde. In Roskilde recreational hunting is a major incentive for planting of woodlots (Kristensen et al., 2013). A recreational forest (106 ha) has been planted between 2001 and 2009. The forest is multipurpose: to increase access to nature and protect ground water reservoirs. In Greece it is mostly the Government, which may implement large afforestation schemes – mostly with European funds. In 2006 large forest fires destroyed however a lot of forest – fires which could also be a result of climate change. In Romania there is a National Afforestation Programme implemented by the Government, and financial support is offered through RDP for the first afforestation of agricultural land. Funds from the state or from the forest improvement fund have been made available for afforestation of degraded agricultural land. In the protected part of Stăncuţa also the EU and World Bank Prototype Carbon Fund were accessed for the forest ecological reconstruction through the planting of native species. In Heerde afforestation may take place by newcomers in a peri-urban area, which

have new land use strategies and ambitions that can include afforestation. In Portofino natural succession leads from abandoned farmland towards a ruderal stage, to macchia and finally Mediterranean forest (Pedroli et al., 2013).

Table 3: Drivers of change, processes behind land use change in the case study areas

Area	Drivers of change	Technology	Economy and market		Transport and infrastructure			Environmental policy and legislation				Environment	
	Processes Land use type	Agro-technological Innovations	Globalisation	Market forces Food\Feed\Fibres	Urbanisation\sprawl	Roads \ infrastructure	Tourism	Protective designation (N2000, Forestry acts)	Zoning	RDP-schemes	Energy policy	Natural succession	Climate change
Lesvos (Greece)	Olive groves		x	x	x	x	x	x	x	x	x	x	
	Forest				x			x			x	x	
	Shrubs											x	
	Crops	x		x	x				x	x			
	Grassland			x						x			
	Build-up area		x		x	x	x	x	x	x			
	Trade / manufacture		x	x	x	x	x	x	x				
	Bare ground											x	
Reichraming (Austria)	Forest		x				x	X			x		
	Crops	x		X				X		x			
	Grassland	x	x	X			x	X		X		X	
	Build-up area												
Roskilde (Denmark)	Forest			x	X			X	x	X			
	Crops	X		X	x				X		X		
	Grassland	x		x	x			X		x			
	Build-up area				X	X			X				
	Trade / manufacture				X	X			X				
	Wetland	x						X		x			
Heerde (the Netherlands)	Forest						X	X	x		x		
	Crops	x		X	x					x			
	Grassland	X	x	X	x								
	Heather & moors						X	X	x		x	x	
	Build-up area		X		X	x	x	x	x				
	Trade/ manufacture		X	x	x	x			X				
Portofino (Italy)	Olive groves		X	X	x	X	x						
	Forest			x				X	x		x	X	x
	Macchia/shrubs		x									X	
	Crops		x	X			x						
	Built-up areas				X	x	x	X	x				
Stăncuţa & Răteşti (Romania)	Forest							x		x			
	Crops	X	x	X	x				x	x	x		x
	Grassland		x		x				x			x	
	Build-up area		x		x				x				
	Wetland	X			x		x	x	x			x	x

Text box: Explanation of change processes mentioned in Table 3*:*

- Agro-technological innovations include agricultural developments which have to do with improved technology (mechanization, irrigation), intensification and specialisation. These can be driving forces in change of crops, lay-out of fields and parcel size or scale of production.

- Globalization is the process of international integration arising from the interchange of world views, products, ideas, and other aspects of culture. Advances in transportation and telecommunications infrastructure, including the Internet, are major factors in globalization, resulting in cultural change Market forces are economic factors which have to do with the pricing of agricultural production, the food/feed/fibres. Also planting of energy crops can result from these drivers. These can be strong incentives for land use change, but are often intertwined with policies affecting pricing such as the Common Agricultural Policy.

- Urbanization processes can be twofold: people moving to larger towns or even abroad, as well as a reverse movement into the rural areas, which results in urban sprawl usually: housing for urban residents, or in some cases for industrial or trade purposes.

- Roads and infrastructure are drivers on their own, which speed up rural transformations and economic development.

- Tourism can be low-impact or high density tourism, and all its required services.

- Zoning is land use planning in a local or regional planning framework, which usually prohibits uncontrolled development

- Protective designations include legislation as the Birds- and Habitats Directive (N2000), Nitrate Vulnerable Zones, forestry acts, or urban development acts. They are not directly related to the financial regulations such as the subsidies (below), but subsidies can be directed towards objectives of these designations.

- RDP-schemes include the financial schemes resulting from policies, in particular the Rural Development Policy RDP, the Agri-environmental schemes and the Least Favoured Areas subsidies.

- Energy policies are national or European policies to stimulate production of biomass for energy, or other means for producing energy such as solar power or windmills.

- Natural succession is the spontaneous development of the vegetation, towards a kind of natural equilibrium. In the case of land abandonment, this often results in development of shrub or semi-natural afforestation.

- Climate (change) is a driver resulting in adapted technologies, but also resulting in land degradation and (sometimes) increased production.

The period of change differs, but usually extends over several decades. In Lesvos we observe that changes in olive groves, which are dominant, occurred some decades ago, but are now fairly stable. Urban area and trade and manufacture have been steadily increasing. In Reichraming area changes occurred also some decades ago, and grasslands are currently still in decline. Roskilde has only recently been changing, mostly since 1995. This is related to [the change in counties, resulting in centralization of planning]. Heerde has been rather stable, due to legislation not much land conversion takes place. Also here a gradual expansion of build-up area and trade and small industrial sites takes place over the past 50 years. For Portofino counts that changes in forests happened after World War II, when many of the intensively managed (Chestnut) plantations were abandoned, this falls outside the observed period after 1972.

All in all no clear patterns in land use change are observed, except for that all areas have different patterns, which cannot be linked directly to certain policies.

Table 4: Period of land use change

Case study area	Land use change	Period when most changes occurred					
	code/ or description (as above)	1972-1980	1980-1990	1990-1995	1995-2000	2000-2005	2005-2010
Lesvos (Greece)	Olive groves	X	X				
	Forest			X	X	X	X
	Shrubs			X	X	X	X
	Crops	X	X	X	X		
	Grassland	X	X				
	Build-up area	X	X	X	X	X	X
	Trade / manufacture	X	X	X	X	X	X
	Bare ground	X	X				X
Reichraming (Austria)	Forest	x	x	x			
	Crops	x	x	x			
	Grassland	x	x	x	x	x	
	Build-up area						
Roskilde (Denmark)	Grassland		X	X	x	x	X
	Crops					x	x
	Forest				x	X	
	Urban						
	Wetland				x	x	x
Heerde (Netherlands)	Forest	x					
	Crops	x	x				x
	Grassland	x					
	Heather & moors	x					
	Build-up area	x	x	x	x	x	
	Trade/ manufacture	x	x	x	x	x	
Portofino (Italy)	Olive groves	x	x	x	x		
	Forest						
	Macchia/shrubs	x					
	Crops	x	x	x			
	Built-up areas	x	x	x			
Stăncuţa & Răteşti (Romania)	Forest					x	x
	Crops	x		x	x	x	
	Grassland				x	x	
	Build-up area	x				x	
	Wetland	x					

3.4 Landscape structure changes

3.4.1 Landscape metrics

We used landscape metrics to assess the landscape composition and landscape change over time of the different case study areas. Landscape metrics describe spatial patterns which are the result of landscape forming processes. We calculated different indicators, such as the mean patch area (AREA MN), patch density (PD), and mean CPA shape index (CPA). For the formulas see Mcgarigal et al. (2002).

The metrics were calculated for the same area, to assess changes in landscape over time – i.e. they were not used to compare the areas among each other, since the outcome is strongly related to the landscape type, mapping process and map scale. For all case study areas the more detailed local map was used (Table 2), for Reichraming the GLC map was used.

The results express partly the landscape and complexity of the landscape pattern; to some extent they also illustrate visual changes. For most areas we see an increase in the number of patches NP and patch density PD, as well as for Total edge TE and Edge length ED (Lesvos, Reichraming), a huge increase however for Portofino, Stăncuţa and Răteşti a slight decrease (Roskilde) resp. increase (Heerde).

An increase for NP and PD is strongly correlated with a **decrease** in mean patch area (AREA_MN). We observe therefore a decrease for Lesvos and Reichraming, Roskilde remains the same, a very strong decrease for Portofino, Răteşti and Stăncuţa. The mean Shape Perimeter-area ration (PARA_MN) decreases for Lesvos and Roskilde, increases slightly for Reichraming and the Netherlands and shows again a large increase for Portofino, Stăncuţa and Răteşti.

The Contagion index CONTAG measures the extent to which patch types are aggregated or clumped (i.e., dispersion); higher values of contagion may result from landscapes with a few large, contiguous patches, whereas lower values generally characterize landscapes with many small and dispersed patches. The Contagion and Shannon diversity index (SHDI and SHEI) does not change much for most cases.

We see a clear pattern of **strong increase for a set of parameters** (NP=Number of Patches, PD=Patch density, TE=Total edge, ED=Edge density, PARA_MN= Shape Perimeter-area ration (Mean)) and a strong decrease (AREA_MN=Patch area (mean)) for Lesvos, Portofino, Răteşti and Stăncuţa, all southern and eastern European countries and to a lesser extent for Reichraming.

3.4.2 Visible landscape change

The qualitative description below presents most important changes occurring in our case study areas. They are not necessarily the same as the observed land cover changes (par. 3.2, Annex 1) although overlap is likely.

Lesvos' landscape changes

Recent changes include agricultural land abandonment (e.g. due to high production cost), land reclamation (conversion of natural ecosystems to cropland or pasture) and cultivation/ land cover change (Kizos et al., 2010).

The most widespread land use change is the abandonment of olive groves (especially in mountainous areas), followed by the residence and finally by the conversion to pasture (Kizos and Spilanis, 2004). The last decades, there are various forms of abandoned olive oil productions, which have varying impacts on the landscape (Kizos et al., 2010; Kizos and Koulouri, 2006). Maquis vegetation follows the abandonment of olive trees. They also include development of new houses, development of infrastructure (new roads, highlighting monuments, sports and recreation facilities, public spaces, expansion of ports, marinas, etc.) and business investments (e.g. development of alternative forms of tourism. Furthermore olive groves are being replaced by wholesale and manufacturing industrial development along the National Road. Migration occurs from rural villages to the city of Mytilini and suburban locations, as well as into satellite villages.

The Forested land increases, mainly because of the abandonment of olive groves. The Forestry Acts stimulate the maintenance of forest land (especially after the process of natural succession). Forest fires also affect land use change. Such fires are said to be caused by land grabbers, out of investors' interests, human carelessness, by stock-farmers (to increase the grazing for their sheep and goats), etc. Since 2011 there is an increased demand for firewood as a result of the crises.

There has been a decrease of crops between 1960-1990, due to the expansion of olive groves (possibly due to the introduction of subsidy schemes). A small increase of crops (either by replacing olive groves or by growing with olive trees) after 1990 is observed nearby settlements, possibly due to the rise of hobby farming in Lesvos (for self-sustainability reasons), but also as an alternative crop cultivation for full-time farmers. In addition, there is a small but continuous decrease in the areal extent of rangelands (either they turn to forestland, brush or sometimes into olive groves).

Along the National Road a wholesale and manufacturing industrial development took place replacing olive groves (mostly), due to the construction of the National Road and of the Urban Development Plan of Mytilene. Tourism's impact on trade/ manufacture sector is low.

Heerde landscape changes

Heerde saw a large change over the past years. The oldest maps from the beginning of the 20th century mark the decline of natural habitat, the forest, heathers and moors which were converted to productive land. In more recent history we see that the process has been finalised, conversion does not take place much anymore from 1960 onwards. From than onwards, there was a small decline in heathers and moors, and an increase in forest area. However, the landscape changes as a result of land rationalization, which results in removal of landscape elements, hedgerows, single trees, ponds, natural brooks etcetera. The pattern of fields changes, although the average patch size increases: this is probably a result of the conversion of large extended natural areas, heathers and moors, into smaller farm parcels. Also the expansion of settlements has impact on the openness of the countryside, especially in this region (Veeneklaas et al., 2004).

Roskilde landscape changes

Around Roskilde the landscape is becoming more forested and therefore closed although still at a small scale. This is caused most and for all by farm land afforestation and larger projects on public land as well as hedgerow planting. Considering the habitats (mentioned in Table 1) which impact most the openness of the landscape and landscape structure, most important are the structures: buildings and urban areas. These are present in most areas (Table 6). In particular Lesvos and Portofino, both Mediterranean region, have a large number of structural landscape habitats.

Portofino landscape changes

Over the recent decades there has been a strong pressure on the coastal area of Italy, a spread of villages and towns due to economic activities as well as tourism occurred with detrimental effects on the coastal zone. Portofino village forms an attractive site for people to have second houses, and for investors to develop recreational facilities. Inside the Park and buffer zone construction and building of houses is very much restricted. It might merely be repair and maintenance, and in some cases (illegal?) expansion. The built-up areas are often just outside the buffer zone of the park where urban development is proliferating.

Poor perspectives for agricultural land use lead to negligence of landscape management. Many agricultural lands were abandoned over the past 40 years. Land degradation as a result of abandonment occurs mostly on the terraced steep slopes of the park. Farmers brought in soil, filling the back of stone walls, and a "meta-stable system" was created (Van der Sluis et al. 2001). Abandonment of these terraces is not caused by low productivity but merely the labour requirements for maintenance of the terraces. Once these terraces are abandoned, land degradation can occur rapidly, due to lack of maintenance of the stone walls. These negative effects are currently progressing, since people find it too difficult to return to these steep lands.

Another important process is natural succession, after abandonment of agricultural land, macchia develops, followed by forest after some years. The succession process can be reversed though, as a result of fires, which are also part of a natural cycle.

Ratesti and Stancuta landscape changes

In Romania landscape changes have been few. Landscape elements probably disappeared many decades ago, with the industrialization process of farming. Currently a detailed survey is done of landscape elements, and changes over the past decades. The observed changes are limited, mostly clearing of tree rows due to infrastructure development. However, there seems no apparent pattern of landscape elements left. Even forest areas and scrub are very limited in extent; it is mostly large scale open farmland.

The available maps did mostly not allow for an assessment of the changes of visual landscape aspects. Visual qualities of the landscape are defined by structure, scale, pattern, openness etcetera, as described in par. 2.3. Very important in this case are the landscape elements. Important elements in the Mediterranean and sloping areas are the terraces and terrace walls. Hedgerows are important in North-west Europe, for our case study areas in Denmark and the Netherlands, but also in the UK, Germany and France they are important features. Fruit trees can sometimes be included, as well as ponds which were artificial and often had an agricultural function for livestock or watering crops (Bugter et al., 1999; Van der Sluis et al., 1999). An indication of the changes in these elements is found in the farmer interviews held in the case study areas (Table 5). Although there is a general tendency of re-establishment of features (hedgerows, in Heerde in particular), the overall trend has been a decline if we observe a longer time period, which is reported in farmer surveys. The farmer survey asked for the specific interventions, and would therefore not discuss whether existing hedgerows or terraces for that matter are being maintained. The overall trend is therefore likely to be a decline in landscape elements if a longer time frame is observed.

Table 5: Change in landscape elements in the case study areas (data from survey of selected farmers)

Landscape elements	Case study areas (# farmers)	Processes	
Terrace and terrace walls	Lesvos (14)	Terrace walls established. In general declining where farming declines	
Hedgerows	Roskilde (22) Heerde (18) Reichraming (6) Lesvos (2)	Strong decline in the past; currently stabilization, or new hedgerows established	
Fruit trees	Reichraming Heerde	Probably declining, not replaced	
Ponds	Roskilde (14) Reichraming (11) Heerde (2) Portofino (1)	New ponds established with farming subsidies	

Except for the landscape elements, there are other features, landscape forming habitats which define very much the landscape. Most important vertical structures (selected from Table 1), are presented in Table 6. These structures are mostly build-up areas, forest and scrub land and stone walls and terraces. Change in forest areas are well described in the analysis of land cover change. The build-up areas, or more particularly urban sprawl is in some cases visible, but the visible impact may be much more than appears from land cover change. The stone walls and terraces, finally, are only mapped for Portofino area, with an indication of the status of the terraces (Figure 16). For the other areas no reliable maps are available.

Table 6: Presence of landscape forming habitats in the case study areas

	Lesvos, GR	Reichra-ming, AT	Roskilde, DK	Heerde, NL	Portofino, IT	Stăncuța & Răteşti, RO
Build-up areas	x	x	x	x		x
Woody crops	x				x	
Geomorphologic features	x				x	
Scrub	x	x		x	x	x
Forest	x	x	x	x	x	x
Woody landscape elements	x		x	x	x	
Stone walls & terraces	x				x	

4 Discussion

4.1 Introduction

Land use is continuously changing in response to environmental conditions, socioeconomic and cultural factors, technological changes and policies (Bürgi et al., 2004; Primdahl et al., 2013b; Veldkamp and Lambin, 2001). Overall land use processes have been dynamic in all case study areas. The processes as described in 1.1 (like intensification and extensification, agricultural expansion and land abandonment, farm restructuring) occurred in all case study areas, to a different extent.

4.2 Case study area changes

The trend of intensification and urbanisation on one hand, and land abandonment, as report by EEA (2010) is also observed in the case study areas. However, there are still remarkable differences in trends in our areas.

Overall the changes are rather small, in our study areas. In most cases it is less than 10%, which is surprising considering the time period which spans often decades. Portofino has changed very much, but as the map shows, most changes took place in the natural area, and the changes are due to natural succession and probably also the occurrence of the frequent fires occurring in the area (Pedroli et al., 2013; Van der Sluis, 2002). The change for Reichraming (42%) is illustrative for the quality of the map data used, this figure is based on the Global Land Cover map, as explained in next paragraph.

This probably also points to a more general problem, the quality of vegetation or land use mapping. If the mapping was done more accurately, with more detail, much more reliable results are found. The quality of the maps is dependent on the available map data and imagery which was used, the method of classification etcetera, which leads to differences in reliability between the maps of case study areas.

An analysis for each polygon is, besides being complex, often not useful either. Differences in mapping or classification accuracy lead to errors, a shift of parcel boundaries by five metre can result in a large number of perceived changes which are not real changes occurring.

Case study area	Period	Years	Change (%)
Lesvos	1981-2004	23	3
Reichraming	2005-2009	4	42
Roskilde	1990-2011	21	5
Heerde	1995-2004	9	8
Portofino	1974-2000	26	34
Stăncuţa	1980-2003	23	11
Răteşti	1980-2003	23	13

One would expect three major regions where changes occur in land use intensity: areas with good farming conditions, where farming has priority; upland areas, with severe natural limitations, where farming is in decline; and newly 'industrializing' farming areas, where land use changes were dominant (Eastern Europe) (Baumann et al., 2011; Kuemmerle et al., 2009; Plieninger et al., 2006; Wascher et al., 2008).

Lesvos: The total change in land use is limited, only 3 % since 1981. Most important change is a decrease in olive farming, and an increase of tourism. The changes seem to be concentrated as expansion of settlements, this however is also a result of the mapping detail. Most change occurs on the Eastern part of the mountain range, along the main axis of development (the main road from the airport towards Mytilini, and further north. There are indications that second houses or residential homes for tourism expanded in the country side, which may not be visible in the maps. The marginalization of farming is not always visible as land use change (yet). In some cases it does lead to land abandonment, followed by development of shrub land and later forest. Almost all drivers of change affect olive groves. Urbanisation/sprawl seems to be most important driver in the countryside.

Reichraming: Based on the Global Land Cover map for Reichraming it is difficult to see clear patterns of land use change. Most of the area is forested, and farming is small-scaled, concentrated in the valleys but mostly in mosaic pattern. Technical problems in map classification (see also par. 4.3) also hinder good analysis, as does the short period which was observed. Important processes are however the 'restructuring' of farms. Small farms disappear, or are observed in larger farms, larger farms grow. Most farms are family farms. There is a tendency to decrease the work load, to make it attractive for the youth to continue farming. Most important drivers are the economy and market, but also subsidies and tourism influence land use.

Roskilde: The most important land use change occurring is the decrease in cropland and grassland (-3,7%) and an increase in settlement and forest (+3,3%). The urban sprawl is widespread, and leads to an increase in hobby farmers or 'life style farmers'. The changes are occurring all over the area, and does not seem to be concentrated to the zone adjoining Roskilde. The planting of hedgerows is popular in Roskilde area, and there has been a net increase of hedges. However, also ponds have been dug with use of subsidies. Urban sprawl is the most important driver of change, which affects all other land use. Spatial zoning is also important, affecting both productive areas and build-up areas and 'trade and manufacture', which are often found in peri-urban areas.

Heerde: Land use changes have been fairly limited in Heerde area. A decrease in grassland is partly compensated by an increase in cropland. Long term changes have been opposite though. Historical maps show that large land use changes occurred at the beginning of last century, with conversion of natural heathers and moors to farmland and forests. Nowadays changes are limited also due to spatial planning and zoning of the area. Natural areas are protected and cannot be converted to other land use. We see therefore that the observed changes occur most in the east of the area, partly in the floodplains, but even more around the settlements along the main road. Also here a very important driver is the urban sprawl, which comes from nearby urban centres such as Zwolle. Natural land use types are mostly affected by environmental policy and legislation, whereas productive land use is affected by economic and technological drivers.

Portofino: Most important land use change is the further decline of farming (-4,9%) and land abandonment (+3,6%). This is only since 1974, if we consider a longer period from 1936 onwards, productive land decreased from 572 ha. to less than 398 ha. The other important land use change is the (forest) succession: abandoned land becomes overgrown with macchia, which develops into forest. In the past the forest was intensively managed, for Chestnut production as well as for charcoal for the cities. This has been abandoned, which has resulted in partly uniform forest stands, with a dense undergrowth since forest management stopped. The fame of Portofino attracts well-to-do people, as well as many tourists. Like in other areas, urban sprawl and settlement is important. As a result of environmental protection this is limited to the fringes of the park and to the buffer zone, and mostly involves the conversion of old farm houses an farmsteads towards residential houses or villas.

Stăncuţa and Răteşti: The changes in those two areas have been limited (11% and 13% respectively), which is surprising considering the huge changes that have taken place in the Romanian countryside. However, the timeframe from 1980 till 2003 may be of influence, the articles discussed report of a period in which land

abandonment took place, and a restructuring of farm land after the abandonment of large state farms. Overall there has been a decrease in productive farm land in Răteşti by -4%. Housing and build-up areas increased both in Răteşti and Stăncuţa. Both areas are characterised by wide open agricultural plains, with few hedgerows, tree rows etcetera, which have been fairly stable over the last decades. In Stăncuţa area the river and adjoining wetlands from the Danube is an important feature. The most important drivers of change are urbanisation and urban sprawl, as well as zoning.

We have chosen to do a general analysis of change. Although we initially intended to describe changes and trajectories of change based on the overlay results from the maps, we concluded that this was not effective: in many cases the map quality was insufficient, due to the mapping techniques used in some of the countries: land cover was mapped from aerial photographs or satellite imagery, without reference to the older map. As a result, many slivers occurred, because of digitising errors. The net change in land use is therefore fairly reliable, since such errors 'average out', but detailed analysis of such changes would not be possible: a shift of boundary could easily result in increase of terraces on one side, decrease of terraces on the other side of the studied polygon, although there is no actual land cover change.

4.3 Comparison of the Global land cover map

We analysed ESA Global Land Cover data for the case study areas (Table 7). All areas combined show an increase in productive land in all case study areas of 3%, despite the relatively short period of only 4 years. For the same period, non-productive land decreased for all areas except for Heerde, which may be explained from the protection of forests and other natural areas (Hauser, 2012) which inhibits conversion of land towards productive land. The trends we found for GLC-data for a short period of 4 years were not always in line with the longer term changes we observed from the land cover maps for each country.

The classification for GLC seems not always consistent, in particular for complex vegetation patterns, crops such as olive yards and gardens. Observed changes for Lesvos and Portofino case study areas were likely to be a result of changes in the classification algorithm – which may also be a result of the different organisations (ESA and JRC) that had the lead in the classification process.

The ratio of productive land versus non-productive land is an important indicator for land use intensity. This ratio was compared for our case study areas on the basis of GLC maps. All areas show an increase in productive land, except for Heerde, which was stable in this period (Table 7).

The comparison of land use totals between two years is not necessarily representative for the change which occurs. In particular for vegetation types which consist of complex vegetation patterns the result of classification at pixel level may show changes which do not occur at the total land use cover. Illustrative is the change for Reichraming (42%) on the Global Land Cover map. If we compare this with the statistics, we see small changes only which do not reflect such large change (Table 7).

In almost all areas mosaic cropland and grassland has increased: only in Heerde there seems a shift towards more grassland, and in Reichraming mosaic grassland/forest decreased by -5% (Table 7). Rainfed cropland decreased slightly in Heerde and Roskilde area. Sparse vegetation decreased very much in all areas, it is not clear if this is a methodological problem, or a real change, e.g. maturing of ruderal areas or forest succession. Heerde has an enormous decrease in broadleaved forest, at the same time an increase in closed to open forest, which probably is a result of classification method as well.

Overall conclusion is that the Global Land Cover maps are not always reliable, due to the classification method, and the use of mosaic vegetation classes. Also if we compare the GLC with the other land use maps, the trends are often not confirmed, which underlines the limitations for the GLC maps.

Table 7: Change in land use and productive land from 2004-2006, and 2009 based on Global Land Cover. Colours indicate small decrease, large decrease, small increase, large increase

	Vegetation cover	Short name	Lesvos	Portofino	Heerde	Roskilde	Reichraming	Stăncuţa	Răteşti
Class	**Productive land**		Change	Change	Change	Change	Change	Change	Change
14	Rainfed croplands	Rainf_crop	0%	2%	-3%	-1%	0%	2%	1%
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	MosaicCrop/veg	5%	1%	-4%	8%	6%	12%	1%
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	MosaicVeg/Crop	6%	8%	1%	9%	6%	3%	4%
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	MosGrass/ForShr	13%		9%	1%	-5%	0%	2%
	Average		**6%**	**4%**	**1%**	**4%**	**2%**	**4%**	**2%**
	Non-productive land								
50	Closed (>40%) broadleaved deciduous forest (>5m)	ClosedBrLfDecid	-4%	-25%	7%	3%	-1%	2%	0%
70	Closed (>40%) needleleaved evergreen forest (>5m)	ClosedEvergr	0%	-4%	1%	0%	0%	-1%	0%
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)		0%		-4%	0%	-2%	-1%	0%
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	Closed/openMix	0%	21%	6%	0%	2%	0%	0%
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	MosForShrGras	2%		4%	-1%	-3%	0%	0%
130	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	ClosOpenShr	3%	-1%		0%	0%	0%	0%
140	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	ClosOpenGrass	0%		-13%	-1%	0%	0%	0%
150	Sparse (<15%) vegetation	SparseVeg	-24%	-2%	-5%	-12%	-3%	-15%	-7%
180	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water		0%			-8%	0%	-1%	
190	Artificial surfaces and associated areas (Urban areas >50%)	Artificial	0%	0%	0%	0%	0%	0%	
210	Water bodies	Water	0%	0%	0%	0%		-1%	
	Average		**-2%**	**-2%**	**0%**	**-2%**	**-1%**	**-2%**	**-1%**

4.4 Drivers of landscape change

Legislation, environmental policy is a strong driver for many more sectors than just protected areas, it also affects build up areas, grasslands and crops. Driving forces with less influence on other land uses are e.g. technology, climate change or energy policy. However, this is based on expert knowledge. Quantification of the drivers is difficult, although possible through Fuzzy Cognitive Mapping, which formalises procedures of expert consultations (Van der Sluis et al., in prep.).

The environmental, policy and legislative drivers often affect many sectors, e.g. designation of N2000 has influence on almost all sectors.

Another relevant observation is that policy and legislation is obviously very influential. It can balance to some extent development, and market forces that also exert much influence on spatial development. The aspect of governance and how institutions involved in the implementation of policy function in the end will be very decisive in the effectiveness of policy (Frederiksen et al., in prep.).

The environmental zones are based on a classification of the European environment, an analysis of the 20 most relevant environmental variables, which resulted in a classification into 13 zones (Metzger et al., 2005). For these zones we may expect that driving forces differ. However, environmental drivers don't seem overriding in the system, a driver as climate change affects certain land uses but not in all zones, they seem in particular influential in the Mediterranean zone. The natural succession occurs mostly in areas where land abandonment takes place, and other drivers such as agricultural development seem to decline, or are absent.

4.5 Landscape impacts

Urbanisation, industrialisation, and intensive agriculture often result in rapid landscape changes, losses of ecological capacity, diversity, and scenic beauty, as well as damage to historically valuable cultural landscape. The observed changes differ in their impact at landscape level. These problems have been analysed for Europe (Pedroli et al., 2006) as well as at the local scale level (Van Eetvelde and Antrop, 2009).

Where possible a qualitative assessment was done, the storylines for the landscape changes were presented, However, also here the sources are scarce and could not always be related to the patterns observed in the maps. In some cases oral sources were used, input from experts in workshops (Van der Sluis et al., in prep.), as well as published sources. This gives indications of change, however, no conclusive image yet.

This report presents a first approach for the assessment of the visible landscape changes. Very important in this case are the landscape elements: the terraces and terrace walls, the hedgerows, and ponds. An indication of the changes in these elements is found in the farmer interviews held in the case study areas (Table 5). Although there is a general tendency of re-establishment of features (hedgerows, in Heerde in particular), the overall trend has been a decline if we observe a longer time period, which is reported in farmer surveys. The farmer survey asked for the specific interventions, and would therefore not discuss whether existing hedgerows or terraces for that matter are being maintained. The overall trend is therefore likely to be a decline in landscape elements if a longer time frame is observed.

There are other features which define very much the landscape, the vertical structures. These structures are mostly build-up areas, forest and scrub land and stone walls and terraces. Change in forest areas are well described in the analysis of land cover change. The build-up areas, or more particularly urban sprawl is in some cases visible, but the visible impact may be much more than appears from land cover change. The stone walls and terraces, finally, are only mapped for Portofino area, with an indication of the status of the terraces (Figure 16). For the other areas no reliable maps are available, and an assessment with e.g. Google Maps was not possible.

4.6 Farming typologies in relation to landscape change

Based on the characteristics of land use and changes occurring, we would come to a grouping and description of the case study areas which differs from the grouping in Figure 1. (NB: text partly from S. Kristensen & A. Buschk, unpublished):

Peri-urban landscapes (Roskilde and Heerde)

These landscapes have been characterised as being the most dynamic landscapes, located on the fringe between urban and more traditional landscapes and giving rise to innovative, contrasting and sometimes conflicting land use and production strategies (Antrop, 2000; Van Eetvelde and Antrop, 2004). For example, the proximity to urban areas may generate demand for recreational areas and activities (eg. hiking and camping facilities, dog training and horse riding), niche production (eg. berry-picking and roadside sale of farm produce) and may thus stimulate the survival of agricultural production which would otherwise be unprofitable. In contrast, the noise and smells associated with conventional agricultural production may lead to conflicts between the existing farm population and newcomers. Some newcomers may have a very specific land use strategy, involving extensification of land use (afforestation, pond digging) for amenity purposes (Busck et al., 2006; Meeus and Gulinck, 2008; Præstholm and Kristensen, 2007; Zasada, 2011). Following from these reflections, we expect complex patterns of land use changes, due to a heterogeneous landowner population and socio-economic patterns, which may both stimulate and reduce interest in landscape activities.

Landscapes with marginal potential for agriculture (Reichraming, Lesvos and Portofino)

Many areas in Europe are characterised as marginal agricultural landscape where challenges of accessibility and cultivation make agricultural production expensive and non-competitive (eg. mountainous areas, islands, remote areas). These areas are faced with depopulation as farms close and young people move away in search of employment (Gaube et al., 2009; Kizos et al., 2009; Pedroli et al., 2013; Singh et al., 2010; Terkenli, 2012; Van der Sluis, 2002). In some areas, tourism is an option for employment and even for other on-farm gainful activities, if accommodation and catering are relevant. Some areas may contain large nature values which are protected as national parks or other designations and while this may attract tourism, it can also entail conflicts with traditional agricultural production if conservation interests conflict with production interests. We expect that most landowners in areas with a marginal potential for agriculture in general are not very interested in landscape activities, as land abandonment, migration of young people and decay of traditional production are major development constraints. However, in some cases landscape management can form part of the ecotourism model, as with 'agriturismo' in Italy. For some, the use of subsidies for landscape restoration, especially in areas with large nature and conservation interests may be a driver for land use change.

Former socialist landscapes (Stăncuţa and Răteşti)

During the Soviet period, collective farming dominated the rural landscapes of all former East-European countries. Land improvement and large scale production created mono-functional landscapes characterized by large field units where little nature was left. Following the collapse of the Soviet system in 1989, these landscapes have experienced massive transformation. They are frequently associated with the polarisation of the farm structure between large scale modern farm companies and very small subsistence farms which can be called "peasant farming" (Müller et al., 2009; Vadineanu et al., 2003). We expect engagement in landscape activities to be quite modest, as there is limited tradition for landscape management and many small farms are struggling and have limited resources for these activities.

5 Conclusions and recommendations

Conclusions

- Land cover changes in the analysed case study areas have been generally fairly small over the last 20 years. However, within the areas, there have been more frequent changes which are not reflected in total areal of certain land use types.

- The important drivers in the areas we have assessed, are: land use change are land use zoning, environmental policies and protective designations. This implies that the institutional issues are important aspects to address, if real policy outcomes are to be expected (Frederiksen et al., in prep.).

- The Roskilde and Heerde cases would qualify as peri-urban areas, with all aspects related to urban environment. Farming is important but an increasing share of the population has no real attachment to the farming sector. Still the landscape is important, for the farmers as well as the new population.

- The Portofino, Lesvos and Reichraming areas can be classified as traditional land use systems (low intensity tree crops and low-intensity livestock raising in mountain areas where farming is in decline (Plieninger et al., 2006). Landscape has been neglected, common are processes of land abandonment and de-population. Only where extensive forms of tourism develop landscape management activities, or sometimes restoration, is an option.

- The Stăncuţa and Răteşti areas show aspects of intensification and extensification of land use. The observed changes are also here rather limited, considering the political changes that have occurred in this same period. There is a polarisation of land use, with large farms intensifying, expanding, and marginal subsistence farming at the same time. Landscape elements have been scarce over the past decades, since the scale enlargement probably took place before the period since 1980, as assessed in this study.

- The Global Land Cover Maps, although useful for European wide assessments, are of little use in complex landscapes as we have assessed in this study. Also the relative short period for comparison, and partly small sized case study areas, make the maps less useful for comparison.

- With the current map data it is very hard to assess the changes in landscape elements, such as tree rows, hedgerows, terraces and stone walls.

Recommendations

As “policy recommendations” the following issues for policy development related to land use change, extrapolated and interpreted from the processes studied, can already be highlighted:

1. *Landscape changes at the European level*
    a. The current knowledge of landscape change is still limited. Indicators used as well as data on land cover change do not unveil the landscape change which is actually occurring. Despite the fact

that this is type of research is very complex, and requires thorough methodologies, this research is urgently needed.

2. *Landscape Monitoring and evaluation*
    a. Monitor landscape changes to assess the effectiveness of policies in the countries, at a local or regional scale. The studies should go beyond the levels of expenditures made: the crucial information is what the effect is at a regional scale of a policy in terms of governance, social, environmental and landscape impacts.
    b. Studies should go beyond the easily measurable effects of land cover and land use impacts.
    c. Quality of the environment should be an intrinsic part of the evaluation process. As workshops and surveys revealed, citizens and experts alike value the landscape change from this perspective.

Literature

Andersen, E., Baldock, D., Bennett, H., Beaufoy, G., Bignal, E., Brouwer, F., Elbersen, B., Eiden, G., Godeschalk, F., Jones, G., McCracken, D. I., Nieuwenhuizen, W., van Eupen, M., Hennekens, S. & Zervas, G., 2003. Developing a high nature value indicator. European Environment Agency, . Copenhagen.

Antrop, M., 2000. Background concepts for integrated landscape analysis. Agriculture, Ecosystems & Environment 77, 17-28.

Baumann, M., Kuemmerle, T., Elbakidze, M., Ozdogan, M., Radeloff, V.C., Keuler, N.S., Prishchepov, A.V., Kruhlov, I., Hostert, P., 2011. Patterns and drivers of post-socialist farmland abandonment in Western Ukraine. Land Use Policy 28, 552-562.

Benini, L., Bandini, V., Marazza, D., Contin, A., 2010. Assessment of land use changes through an indicator-based approach: A case study from the Lamone river basin in Northern Italy. Ecological Indicators 10, 4-14.

Brussaard, L., Caron, P., Campbell, B., Lipper, L., Mainka, S., Rabbinge, R., Babin, D., Pulleman, M., 2010. Reconciling biodiversity conservation and food security: scientific challenges for a new agriculture. Current Opinion in Environmental Sustainability 2, 34-42.

Bugter, R., Van der Sluis, T., Vos, C., 1999. Towards an expert system for pond networks: exploration and use of Life data.

Bürgi, M., Hersperger, A., Schneeberger, N., 2004. Driving forces of landscape change — current and new directions. Landscape Ecology 19, 857-868.

Busck, A.G., Kristensen, S.P., Præstholm, S., Reenberg, A., Primdahl, J., 2006. Land system changes in the context of urbanisation: Examples from the peri-urban area of Greater Copenhagen. Geografisk Tidsskrift-Danish Journal of Geography 106, 21-34.

Cosor, G., Frederiksen, P., Geamana, N., Pilgaard Kristensen, S., Svenningsen, S.R., Sxistou, D., Terkenli, T.S., Pavlis, E., Vadineanu, A., Van der Sluis, T., 2012. Literature study on land use and landscape change as a result of European policies - an overview of institutions and governance structures regarding land use change for different countries in Europe, in: Van der Sluis, T. (Ed.), VOLANTE Project reports, Copenhagen.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260.

EEA, 2010. The European environment — state and outlook 2010 (SOER 2010).

ESRI, 2011. ArcGIS Desktop: Release 10. . Environmental Systems Research Institute, Redlands, CA.

Feranec, J., Jaffrain, G., Soukup, T., Hazeu, G., 2010. Determining changes and flows in European landscapes 1990–2000 using CORINE land cover data. Applied Geography 30, 19-35.

Frederiksen, P., Van der Sluis, T., Vadineanu, A., Gaube, V., Terkenli, T.S., Busck, A., Vesterager, J.P., in prep. Policy drivers of land change – the role of institutions?

Frederiksen, P., Vesterager, J.P., 2013. Policy drivers of land use/landscape change and the role of institutions, VOLANTE Project reports, Aarhus.

Gaube, V., Kaiser, C., Wildenberg, M., Adensam, H., Fleissner, P., Kobler, J., Lutz, J., Schaumberger, A., Schaumberger, J., Smetschka, B., Wolf, A., Richter, A., Haberl, H., 2009. Combining agent-based and stock-flow modelling approaches in a participative

analysis of the integrated land system in Reichraming, Austria. Landscape Ecology 24, 1149-1165.

Hauser, L.T., 2012. A bird's eye view: a case study on the relationship between farm management and 'green veins'in the multifunctional agricultural landscape. . University of Utrecht, , Utrecht, p. 123.

Hazeu, G.W., 2006. Land use mapping and monitoring in the Netherlands (LGN5), Proceedings of the Second Workshop of the EARSeL SIG on Remote Sensing of Land Use & Land Cover, pp. 28-30.

Hersperger, A.M., Bürgi, M., 2010. How Do Policies Shape Landscapes? Landscape Change and its Political Driving Forces in the Limmat Valley, Switzerland 1930–2000. Landscape Research 35, 259-279.

Hersperger, A.M., Bürgi, Matthias, 2009. Going beyond landscape change description: Quantifying the importance of driving forces of landscape change in a Central Europe case study. Land Use Policy 26, 640-648.

Honnay, O., Piessens, K., Van Landuyt, W., Hermy, M., Gulinck, H., 2003. Satellite based land use and landscape complexity indices as predictors for regional plant species diversity. Landscape and Urban Planning 63, 241-250.

Kizos, T., Dalaka, A., Petanidou, T., 2009. Farmers' attitudes and landscape change: evidence from the abandonment of terraced cultivations on Lesvos, Greece. Agriculture and Human Values 27, 199-212.

Kizos, T., Dalaka, A., Petanidou, T., 2010. Farmers' attitudes and landscape change: evidence from the abandonment of terraced cultivations on Lesvos, Greece. Agriculture and Human Values 27, 199-212.

Kizos, T., Koulouri, M., 2006. Agricultural landscape dynamics in the Mediterranean: Lesvos (Greece) case study using evidence from the last three centuries. Environmental Science & Policy 9, 330-342.

Kizos, T., Spilanis, I., 2004. The transformation of landscape: Modeling policy and social impacts on the agricultural landscape of Lesvos. Natural Resource Modeling 17, 321-358.

Knol, W.C., Kramer, H., Gijsbertse, H.A., 2004. Historisch grondgebruik Nederland: een landelijke reconstructie van het grondgebruik rond 1900. Alterra, Wageningen, p. 95.

Kristensen, S.B.P., Gravsholt Busck, A., Cosor, G., Gaube, V., Pavlis, E., T., V.d.S., Terkenli, T., Vădineanu, A., 2013. Landscape changes in Europe: Upscaling results from case studies and cross-region comparisons, VOLANTE Project reports, Copenhagen.

Kristensen, S.B.P., Gravsholt Busck, A., Richard, A.S., T., V.d.S., Bogers, M., Hauser, L., Pedroli, B., Cosor, G., Vadineanu, A., Pavlis, E., Terkenli, T., Gaube, V., Lutz, J., Bartels, L., 2012. Summary reports for each case study including additional data., VOLANTE Project reports, Copenhagen.

Kristensen, S.P., Thenail, C., Kristensen, L., 2001. Farmers' involvement in landscape activities: an analysis of the relationship between farm location, farm characteristics and landscape changes in two study areas in Jutland, Denmark. J Environ Manage 61, 301-318.

Kuemmerle, T., Müller, D., Griffiths, P., Rusu, M., 2009. Land use change in Southern Romania after the collapse of socialism. Regional Environmental Change 9, 1-12.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skånes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T.A., Vogel, C., Xu, J., 2001. The causes of land-use and land-cover change: moving beyond the myths. Global Environmental Change 11, 261-269.

Levin, G., 2007. Relationships between Danish organic farming and landscape composition. Agriculture, Ecosystems and Environment 120, 330-344.

Levin, G., Jepsen, M.R., 2010. Abolition of set-aside schemes, associated impacts on habitat structure and modelling of potential effects of cross-farm regulation. Ecological Modelling 221, 2728-2737.

Mcgarigal, K., Cushman, S., Neel, M., Ene, E., 2002. FRAGSTATS: spatial pattern analysis program for categorical maps.

Meeus, S.J., Gulinck, H., 2008. Semi-urban areas in landscape research: A review. Living Reviews in Landscape Research 2, 1-45.

Metzger, M.J., Bunce, R.G.H., Jongman, R.H.G., Mücher, C.A., Watkins, J.W., 2005. A climatic stratification of the environment of Europe. Global Ecology and Biogeography 14, 549-563.

Müller, D., Kuemmerle, T., Rusu, M., Griffiths, P., 2009. Lost in transition: determinants of post-socialist cropland abandonment in Romania. Journal of Land Use Science 4, 109-129.

Normander, B., Levin, G., Auvinen, A.-P., Bratli, H., Stabbetorp, O., Hedblom, M., Glimskär, A., Gudmundsson, G.A., Indicator framework for measuring quantity and quality of biodiversity--Exemplified in the Nordic countries. Ecological Indicators In Press, Corrected Proof.

Pedroli, B., Pinto-Correia, T., Cornish, P., 2006. Landscape–what's in it? Trends in European landscape science and priority themes for concerted research. Landscape Ecology 21, 421-430.

Pedroli, B., Tagliasacchi, S., Van der Sluis, T., Vos, W., 2013. Ecologia del paesaggio del Monte di Portofino / Landscape Ecology of the Monte di Portofino. (bilingual Italian-English edition) [incl. Landscape-ecological map 1:10,000], Wageningen, 457 pp.

Petanidou, T., Kizos, T., Soulakellis, N., 2008. Socioeconomic Dimensions of Changes in the Agricultural Landscape of the Mediterranean Basin: A Case Study of the Abandonment of Cultivation Terraces on Nisyros Island, Greece. Environmental Management 41, 250-266.

Petit, S., Elbersen, B., 2006. Assessing the risk of impact of farming intensification on calcareous grasslands in Europe: A quantitative implementation of the MIRABEL framework. Ambio 35, 297-303.

Plieninger, T., 2006. Habitat loss, Fragmentation, and Alteration – Quantifying the Impactof Land-use Changes on a Spanish Dehesa Landscape by Use of Aerial Photography and GIS. Landscape Ecology 21, 91-105.

Plieninger, T., Höchtl, F., Spek, T., 2006. Traditional land-use and nature conservation in European rural landscapes. Environmental Science & Policy 9, 317-321.

Præstholm, S., Kristensen, S.P., 2007. Farmers as initiators and farms as attractors for non-agricultural economic activities in peri-urban areas in Denmark. Geografisk Tidsskrift-Danish Journal of Geography 107, 13-27.

Primdahl, J., Kristensen, L.S., Busck, A.G., 2013a. The Farmer and Landscape Management: Different Roles, Different Policy Approaches. Geography Compass 7, 300-314.

Primdahl, J., Kristensen, L.S., Swaffield, S., 2013b. Guiding rural landscape change: Current policy approaches and potentials of landscape strategy making as a policy integrating approach. Applied Geography 42, 86-94.

Rienks, W., Hoek, S., Verweij, P., Lokers, R., Vanmeulebrouk, B., 2008. Eururalis, a discussion support tool for rural Europe, Proceedings of the iEMSs Fourth Biennial Meeting.

Roose, A., Sepp, K., 2010. Monitoring framework for assessing changes of the Estonian rural landscape in adopting European agricultural policies. European Countryside 2, 42-59.

Rounsevell, M., Reginster, I., Araújo, M.B., Carter, T., Dendoncker, N., Ewert, F., House, J., Kankaanpää, S., Leemans, R., Metzger, M., 2006. A coherent set of future land use change scenarios for Europe. Agriculture, Ecosystems & Environment 114, 57-68.

Rounsevell, M.D.A., Pedroli, B., Erb, K.-H., Gramberger, M., Busck, A.G., Haberl, H., Kristensen, S., Kuemmerle, T., Lavorel, S., Lindner, M., Lotze-Campen, H., Metzger, M.J., Murray-Rust, D., Popp, A., Pérez-Soba, M., Reenberg, A., Vadineanu, A., Verburg, P.H., Wolfslehner, B., 2012. Challenges for land system science. Land Use Policy.

Schröter, D., Cramer, W., Leemans, R., Prentice, I.C., Araújo, M.B., Arnell, N.W., Bondeau, A., Bugmann, H., Carter, T.R., Gracia, C.A., de la Vega-Leinert, A.C., Erhard, M., Ewert, F., Glendining, M., House, J.I., Kankaanpää, S., Klein, R.J.T., Lavorel, S., Lindner, M., Metzger, M.J., Meyer, J., Mitchell, T.D., Reginster, I., Rounsevell, M., Sabaté, S., Sitch, S., Smith, B., Smith, J., Smith, P., Sykes, M.T., Thonicke, K., Thuiller, W., Tuck, G., Zaehle, S., Zierl, B., 2005. Ecosystem Service Supply and Vulnerability to Global Change in Europe. Science 310, 1333-1337.

Singh, S.J., Haberl, H., Gaube, V., Grünbühel, C.M., Lisivieveci, P., Lutz, J., Matthews, R., Mirtl, M., Vadineanu, A., Wildenberg, M., 2010. Conceptualising long-term socio-ecological research (LTSER): Integrating the social dimension, Long-term ecological research. Springer, pp. 377-398.

Soler, L.S., Kok, K., Camara, G., Veldkamp, A., 2011. Using fuzzy cognitive maps to describe current system dynamics and develop land cover scenarios: a case study in the Brazilian Amazon. Journal of Land Use Science 7, 149-175.

Stanners, D., Bourdeau, P., 1995. Europe's Environment. The Dobrıs Assessment. European Environment Agency, Copenhagen.

Stobbelaar, D.J., Pedroli, B., 2011. Perspectives on Landscape Identity: A Conceptual Challenge. Landscape Research 36, 321-339.

Terkenli, T.S., 2012. Networks of Dependency and Partnership: problems and prospects of tourism sustainability in the Aegean (Greece) in: Cassar, T.S.T.a.L.F. (Ed.), Contemporary Mediterranean Geographies. Springer Dordrecht.

Vadineanu, A., Adamescu, M., Vadineanu, R., Cristofor, S., Negrei, C., 2003. Past and future management of Lower Danube Wetlands System: a bioeconomic appraisal. Journal of Interdisciplinary Economics 14(4), 415-448.

Van der Sluis, T., 2002. Development of a methodology to analyse land use options for Monte di Portofino, Dep. of Env. Sciences/Alterra. Wageningen University, Wageningen.

Van der Sluis, T., Bloemmen, M., Bouwma, I.M., 2004. European corridors: strategies for corridor development for target species. http://content.alterra.wur.nl/webdocs/internet/corporate/prodpubl/boekjesbrochures/ecnc_compleet.pdf. ALTERRA, ECNC, Tilburg/Wageningen, The Netherlands, p. 33.

Van der Sluis, T., Bogers, M., Kok, K., Arts, B., in prep. Drivers of landscape change in different environmental zones in Europe: a stakeholders' perspective on how EU policies affect the European Landscape.

Van der Sluis, T., Bugter, R.J.F., Vos, C.C., 1999. Recovery of the Great crested newt population (Trituris cristatus Laurenti, 1768) in Twente, the Netherlands?, in: Boothby, J. (Ed.), Ponds & Pond Landscapes of Europe., pp. 235-246.

Van Eetvelde, V., Antrop, M., 2004. Analyzing structural and functional changes of traditional landscapes—two examples from Southern France. Landscape and Urban Planning 67, 79-95.

Van Eetvelde, V., Antrop, M., 2009. Indicators for assessing changing landscape character of cultural landscapes in Flanders (Belgium). Land Use Policy 26, 901-910.

Van Eupen, M., Metzger, M.J., Pérez-Soba, M., Verburg, P.H., van Doorn, A., Bunce, R.G.H., 2012. A rural typology for strategic European policies. Land Use Policy 29, 473-482.

Veeneklaas, F.R., Regt, W.J.d., Agricola, H.J., 2004. Verrommelt het platteland onder stedelijke druk : storende elementen en landschapsdynamiek in de studiegebieden Abcoude en Epe-Vaassen. Natuurplanbureau, Wageningen, p. 102.

Veldkamp, A., Lambin, E.F., 2001. Predicting land-use change. Agriculture, Ecosystems & Environment 85, 1-6.

Verburg, P., Overmars, K., 2009. Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. Landscape Ecology 24, 1167-1181.

Vos, W., Klijn, J., 2000. Trends in European landscape development: prospects for a sustainable future.

Wascher, D.M., 2004. Landscape Indicator Development: Steps towards a European approach, in: Jongman, R.e. (Ed.), The new dimensions of the European landscapes. Wageningen UR Frontis Series, Dordrecht.

Wascher, D.M., Pedroli, G.B.M., Schröder, R.R.G., 2008. Landschapsbeleid in Noordwest-Europa.

Zasada, I., 2011. Multifunctional peri-urban agriculture—A review of societal demands and the provision of goods and services by farming. Land Use Policy 28, 639-648.

Annex 1: Spatial analysis case study areas

Lesvos

The study area lies on the Eastern tip of Lesvos island, around Mytilini city. The area measures 10,870 ha. Most of the area in Lesvos case study area is farmland, of which most (some 50%) is olive groves. Olive growing has a long tradition on the island, and dates back for centuries (Kizos and Koulouri, 2006; Petanidou et al., 2008) In addition there is pine forest, the forest of Kratigos-Amali. However, due to fires the forests have been severely damaged, in particular the fire of 2006 has been disastrous. Mainstay for the people is olive oil production, which is partly for the market, partly for own consumption. Tourism has been gradually increasing; it is mostly small-scale tourism, dispersed over the island with development of holiday houses. There are pockets of tourism development, settlements attracting small hotels and restaurants such as Petra, Molybos, Eressos and perhaps Plomari and Skala Kallonis.

We compared the statistics for the different years, from 1960, 1981, 1990 and 2004. The research area is defined by the communities that were included in the farmers survey (Kristensen et al., 2012). The sample included 45 respondents from the city of Mytilini, and 45 respondents from the nine villages in the case study area: Pirgi Thermis, Pamfila, Panagiouda, Afalonas, Moria, Alifanta, Taxiarches, Agia Marina and Loutra.

Most important change in land use between 1981 and 2004 is the gradual decrease in olive groves (- 2.1%) and an increase in build-up area (+ 2.1 %) (Table 8). The decrease in olive groves is a process since 1960, however, as Kizos and Koulouri (2006) show olives were typically a crop which changed the diverse farming system in a monoculture one century ago. It is a result of the low prices for olive oil on the international market, which makes olive growing unattractive for economic reasons. Even if there are niches such as organic products, local players are not able to exploit them, as they sell in bulk and therefore are unable to fully valorise their product (with some small scale exceptions). Also, the growing of olives is labour intensive, and with an aging population this is more and more difficult. This results in people that resettle in villages or cities, abandoning their olive groves. In some areas (e.g. Moria) people choose alternative crops, and farmers also turn to biological olive oil production.

In Lesvos landscape change as a result of EU policy is slow. Policies also may aim to preserve the landscape. EU policy has mostly impact on the landscape through rural development programs involving agro-tourism and other types of alternative tourism, road building, and development of infrastructures (e.g. Leader, Rural Integrated Programs). Such EU policies have direct or indirect strong impact on landscape (P. Baggelis, pers. com).

If we take a longer time perspective we observe more land abandonment, which leads to urban expansion, urban development plans (the urban area has doubled since 1960). Urban settlement expands as a result of development and expansion of villages, and to a smaller extent expansion of Mytilini. However, there was also expansion of an industrial site along the road Mytilini-Kalloni, from Alifanta to Larsos, for wholesale shops and industrial production, which increases the build-up area (T.S. Terkenli, pers. com). The urbanisation process was strongest from 1960 to 1980. After 1990, the urban settlement boundary on Lesvos changed, these boundaries were extended. There has been a small increase of forest land, as a result of subsidies for reforestation. Forest areas have increased, but part of the forest was destroyed as a result of forest fires after 2004.

All in all the changes are rather small, and don't exceed 2.1 % in all over a period of 25 years, which is a bit surprising considering the long time period.

Table 8: Change in land cover, based on land use maps Lesvos

LAND USE	AREA 1960 (ha)	%	AREA 1981 (ha)	%	AREA 1990 (ha)	%	AREA 2004 (ha)	%	Relative change, 1981-2004	Absolute change, 1981-2004
olive groves	5,493	50%	5,397	50%	5,228	48 %	5,167	48 %	-2.1%	-4.3
coniferous forest	2,647	24%	2,700	25%	2,694	25 %	2,721	25 %	0.2%	0.8
sparsely coniferous forest	201	2%	201	2%	201	2%	201	2%	0.0%	0.4
brush	828	8%	816	8%	814	7%	812	7%	0.0%	-0.5
crops	504	5%	466	4%	436	4%	456	4%	-0.1%	-2.2
grassland	594	5%	584	5%	579	5%	570	5%	-0.1%	-2.4
marsh	35	0%	39	0%	39	0%	39	0%	0.0%	-0.1
build up	377	3%	422	4%	649	6%	649	6%	2.1%	53.8
bare ground	129	1%	149	1%	149	1%	151	1%	0.0%	1.2
airport	25	0%	25	0%	25	0%	25	0%	0.0%	-0.3
not classified	48	0%	67	1%	60	1%	77	1%	0.1%	15.9
SUM	10,880		10,864		10,873		10,868			

Table 9: Global land cover for Lesvos area, for the period of 2005 to 2009

CODE	LAND COVER	2006 (ha)	%	2009 (ha)	%	Rel. change, 2005-2009	Abs. change, 2005-2009
14	Rainfed crop	680	6.15%	646	5.84%	-0.3%	-5.0%
20	Mosaic Crop/vegetation	398	4%	941	9%	4.9%	136.4%
30	Mosaic veget./Crop	-	0%	639	6%	5.8%	0.0%
50	Closed BroadLfd forest	487	4%	84	1%	-3.6%	-82.8%
70	Closed Evergreen forest	2,237	20%	2,264	20%	0.2%	1.2%
100	Closed/open forest	27	0%	48	0%	0.2%	77.8%
110	Mosaic Forest/grass	65	1%	322	3%	2.3%	395.4%
120	Mosaic Grass/Forest	30	0%	1,487	13%	13.2%	4856.7%
130	Closed/Open Shrub land	3,068	28%	3,346	30%	2.5%	9.1%
140	Closed/Open Grass	13	0%	13	0%	0.0%	0.0%
150	Sparse Vegetation	2,935	27%	246	2%	-24.3%	-91.6%
190	Artificial surface	816	7%	768	7%	-0.4%	-5.9%
210	Water	302	3%	254	2%	-0.4%	-15.9%
SUM		11,058		11,058			

The Global land cover data[4] for 2005 and 2009 (Table 9) show an increase of brush (+13%), mosaic grassland (+5%) and mosaic vegetation and crops (+6%). This is mostly at the expense of sparse vegetation, which have been declining in the study area by -24% !

[4] An extensive legend for this table is found in Table 7

This result is quite a contrast with the land use maps of the area. It may show that the GLC classification of olive groves is not clear. Therefore we selected all olive groves in the 2004 Land Cover and combined this with the Global Land Cover map (Table 10). This shows that the classification is highly diverse: 75% of the olive groves is classified in GLC as area with 'sparse vegetation' and 'closed to open shrub land'.

Table 10: Global Land Cover classification of the olive yards

LAND COVER	AREA (ha)	%
Rainfed crop	365	7.0%
Mosaic Crop/vegetation	187	3.6%
Closed Broad leafed forest	355	6.8%
Closed Evergreen forest	103	2.0%
Closed/Open Shrubland	1695	32.7%
Closed/Open Grass	1	0.0%
Sparse Vegetation	2162	41.7%
Artificial surface	241	4.6%
Water	81	1.6%

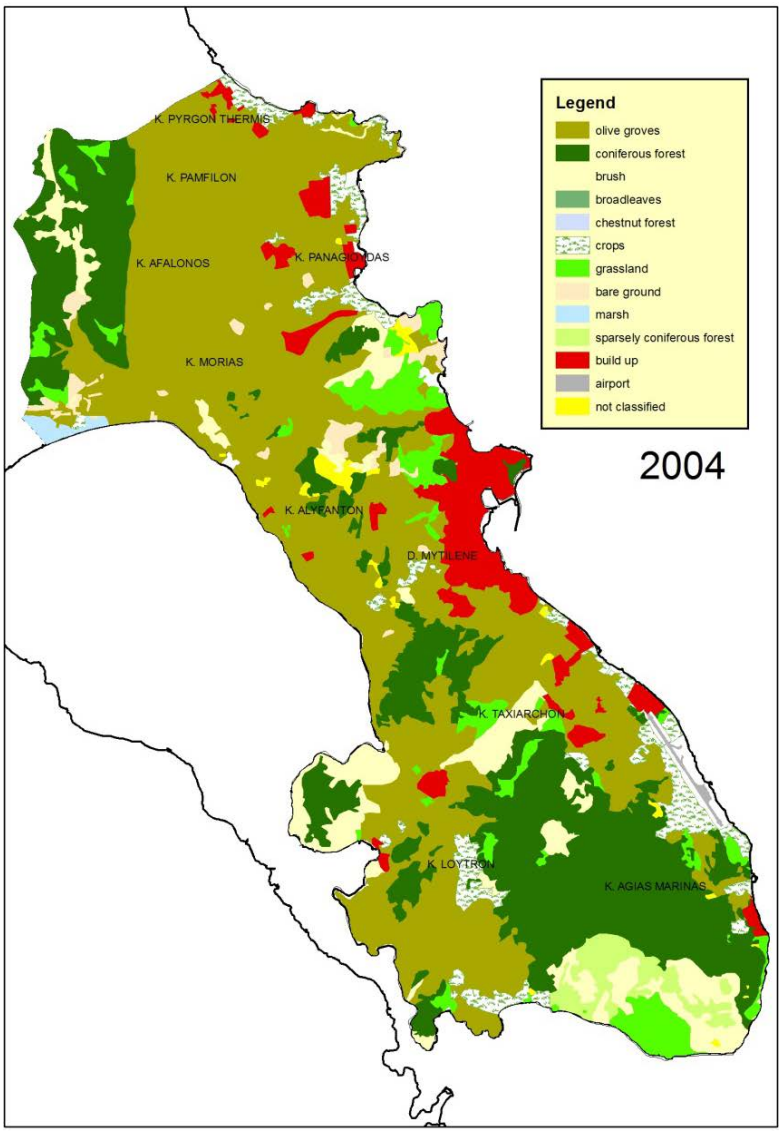

Figure 11: Land cover for the Mytilini case study area (2004)

Overall land use change is limited: some 3% is changed, which means that 97% was stable in the period from 1981 to 2004 (Figure 4). Most change occurs on the Eastern part of the mountain range, along the main axis of development (the main road from the airport towards Mytilini, and further north. Most striking change is the expansion of build-up area. This happens mostly in a concentrated pattern, often adjoining existing town and villages. To a limited extent expansion of forest took place.

Reichraming

Reichraming is located in the province of Upper Austria, the Eisenwurzen area. In the past there has been much mining and metallurgy, but most mines have been abandoned or relocated outside the area. The Eisenwurzen area has marginal agricultural productivity. The forests are encroaching as a result of declining agriculture (Kristensen et al., 2012).The area is dominated by forest which covers almost 80%, in particular in higher regions. It is mostly coniferous forest and mixed forest. Agriculture is mostly done on smaller farms, and the meadows are situated in the valleys and higher up in the Alps. Most of the 60 farmers raise cattle and produce milk. High nature value areas are present. The case study area measures some 100 km2 (Gaube et al., 2009).

There are no detailed land use maps or land cover maps available for Reichraming. We compared therefore the Global land cover maps for 2005 and 2009 (Table 7). Almost 85% of the area is forested, the remainder mostly being cropland (2009).

Most striking change occurs in mosaic cropland / vegetation (grassland/shrubland/forest) increase (+5.9%), and also Mosaic vegetation (grassland/shrubland/forest)/cropland (+6.3 %). The decrease is in Mosaic grassland/forest or shrubland (-5.2%), Sparse vegetation (-3.0%), and Mosaic forest or shrubland/grassland (-2.5%). In fact, these land cover types have rather similar patterns at this scale, the forest area remained the same which may well be explained as that overall land use change was limited.

Table 11: Global land cover for Reichraming area, for the period of 2005 to 2009

CODE	LAND COVER	2006 (ha)	%	2009 (ha)	%	Rel. change, 2005-2009	Abs. change, 2005-2009
14	Rainfed crop	38	0%	13	0%	-0.2%	-65.8%
20	Mosaic Crop/vegetation	93	1%	695	7%	5.9%	647.3%
30	Mosaic vegetation/Crop			649	6%	6.3%	0.0%
50	Closed broadleaved forest	3225	31%	3132	31%	-0.9%	-2.9%
70	Closed Evergreen forest	2030	20%	2011	20%	-0.2%	-0.9%
90	Open forest	175	2%	0	0%	-1.7%	-100.0%
100	Closed/open forest	3149	31%	3356	33%	2.0%	6.6%
110	Mosaic Forest/grass	385	4%	126	1%	-2.5%	-67.3%
120	Mosaic Grass/Forest	721	7%	185	2%	-5.2%	-74.3%
140	Closed/Open Grass	133	1%	96	1%	-0.4%	-27.8%
150	Sparse Vegetation	308	3%	0		-3.0%	-100.0%
190	Artificial surface	6	0%	0		-0.1%	-100.0%
SUM		10263		10263			

Roskilde

Roskilde municipality measures some 212 km2. Most land use in this case study area is agricultural, predominantly crop farming (61%), but also housing and settlements put a large claim on the land (25%). There is a strong urban pressure on this area from nearby Copenhagen (35 km distance), which leads to conversion of land and farms for non-agricultural purposes (Kristensen et al., 2012).

The Land Use/Land Cover (LU/LC) map was analysed for the period 1990-2011 (G. Levin, pers. comm). In the 1990 map, grassland is "overrepresented" (pers. Comm. G. Levin). The information on cropland and partly grassland is derived from the agricultural registers. Until 2010, this information could not be precisely located at field parcel scale. Therefore, a change from grassland to grassland in the maps can also have been a change from cropland to grassland, the decline of -1% may be more. The analysis of land use change during 20 years shows a decrease in cropland by -3%. There is also a slight increase in forest cover, and a decrease in grassland. This decline of farmland is probably a result of an increase in settlements (+2%).

The forest maps for 1950 showed that at that time 238 ha of forest existed (Table 12). In 1990 this area had increased to 723 ha, over the whole period to 2011 the total area has almost quadrupled. In 1950 rural and urban settlements totalled 1128 ha. Also the total built-up area has quadrupled. Lakes measured at 1950 only 250 ha and wetland 1295 ha (Table 12). In particular wetlands have declined, nowadays they measure 473 ha. This is probably a result of land drainage for agriculture.

Table 12: Change in land cover, based on LU/LC maps for Roskilde

	1950 [5] (ha)	1990 (ha)	%	2011 (ha)	%	Relative change, 1990-2011	Absolute change, 1990-2011
Cropland		13583	64%	12959	61%	-2.9%	-4.6%
Grassland	250	1409	7%	1241	6%	-0.8%	-11.9%
Forest	238	723	3%	1040	5%	1.5%	43.9%
Wetland		400	2%	473	2%	0.3%	18.5%
Lake	1295	282	1%	298	1%	0.1%	5.6%
Sea		7	0%	7	0%	0.0%	0.0%
Settlement	1128	4823	23%	5208	25%	1.8%	8.0%
SUM		21226		21226			

The decrease of grassland is related to the reduction in livestock numbers and dairy cattle over the past 50 years. Farms were converted to hobby farms and part time farms. An opposite trend however is driven by 'horsification', the demand for grazing land and stables for horses, as well as the agri-environmental schemes for grassland management.

Cropland has decreased as a result of expansion of settlements, but also gravel excavation and increased forest areas. The Gundsømagle recreational forest was planted in 2001, by 2009 there was some 106 ha. The increase in settlements, both rural and urban, is a bit inflated because cottage areas may be included in the mapping of rural areas. The agri-environmental schemes not only increased grasslands, but also wetlands have increased. Some farmers may have stopped draining their land due to the high costs involved.

[5] The maps for 1950 are digitized maps based on the 1:10,000 maps, digitised in a different manner, and are therefore not entirely comparable with the detailed LULC maps which are grid-based.

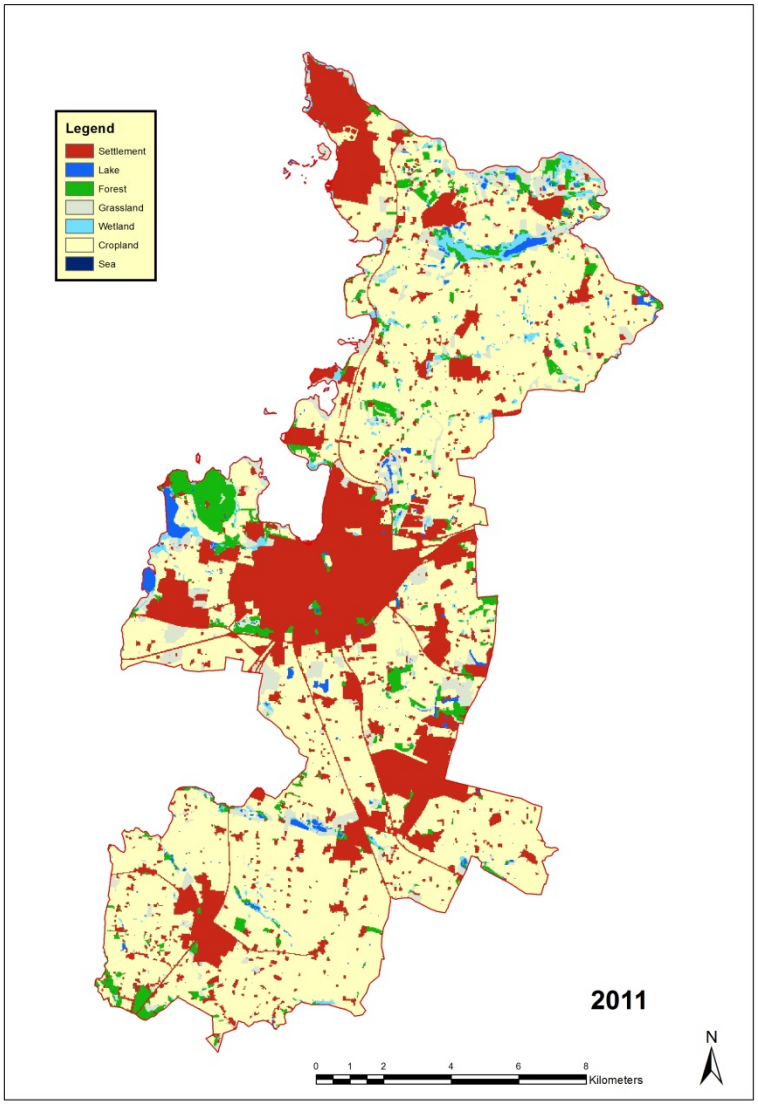

Figure 12: Land cover Roskilde area (2011) (Source: G. Levin, unpubl.)

The hedgerow map is available for 2001 (ref Soren?). Hedgerows form quite a dense network all over the county. The total length of hedgerows is 331 km (for more than 2200 elements), on average the hedges are 150 m (Table 13).

Table 13: Hedges in Roskilde (map 2001)

Hedgerows in Roskilde	
Count	2215
Minimum (m)	3.46
Maximum (km)	2,747.66
Sum (km)	331,102.21
Mean (m)	149.48
Standard Deviation	140.40

The Global land cover data (Table 14) show a decrease in sparse vegetation (-11.6%) and 'closed- to open grassland or forest on regularly flooded' areas' (-7.9%). The latter may be an artefact: although the area is low-lying it is doubtful that it is actually flooded. It would also contradict the LULC comparison, which indicates that wetlands remained the same. Also the observed increase in Mosaic vegetation/crops (+8.4%), mosaic crops/vegetation (+7.2%) is not in line with these findings. The increase in artificial surface (+3.8%) seems correct though.

Overall land cover change is some 5%, whereas 95% remained stable in the period from 1990-2011. It is mostly urban expansion, or expansion of built-up areas, which occurs in particular around Roskilde city, and seems to decrease with the distance from town. Also cropland increases in this area, whereas conversion of land into forest takes place in the areas at some distance from Roskilde.

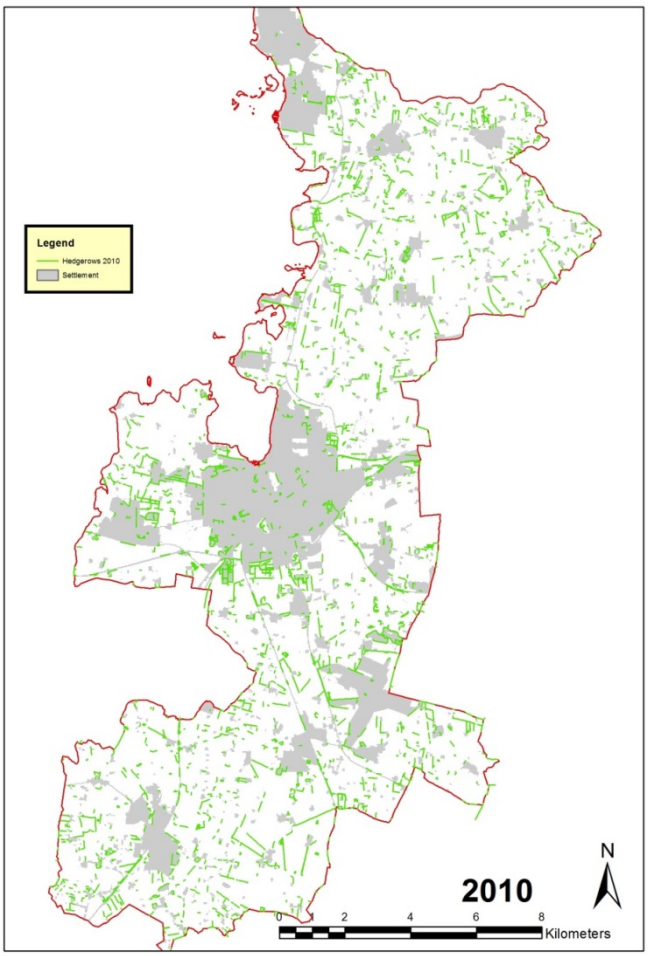

Figure 13: hedges in Roskilde municipality

Table 14: Global land cover for Roskilde area, for the period of 2005 to 2009

CODE	LAND COVER	2006 (ha)	%	2009 (ha)	%	Rel. change, 2005-2009	Abs. change, 2005-2009
14	Rainfed crop	8023	38%	7755	37%	-1.3%	-3.3%
20	Mosaic Crop/vegetation	5798	27%	7323	34%	7.2%	26.3%
30	Mosaic veget./Crop			1793	8%	8.4%	0.0%
50	Closed BroadLfd forest	407	2%	1035	5%	3.0%	154.0%
70	Closed Evergreen forest	108	1%	51	0%	-0.3%	-53.4%
100	Closed/open forest	73	0%	32	0%	-0.2%	-55.9%
110	Mosaic Forest/grass	151	1%			-0.7%	-100.0%
120	Mosaic Grass/Forest	119	1%	310	1%	0.9%	160.7%
140	Closed/Open Grass	183	1%			-0.9%	-100.0%
150	Sparse Vegetation	2608	12%	141	1%	-11.6%	-94.6%
180	Grassland on regularly flooded area	2356	11%	683	3%	-7.9%	-71.0%
190	Artificial surface	1053	5%	1857	9%	3.8%	76.4%
200	Sea	11	0%	33	0%	0.1%	200.4%
210	Water	335	2%	216	1%	-0.6%	-35.7%
SUM		21226		21226			

Heerde

The Heerde municipality is located in the East of the Netherland and is situated along the northern part of the IJssel Valley. Its area encompasses approximately 8035 ha., of which about 167 ha. water. The number of inhabitants is 18.313, the largest settlement is Heerde in the centre. The municipality can be subdivided in to three main landscape zones. West of Heerde is the largest forest area of the Netherlands, the Veluwe. Tourism and forestry are the main functions of this zone. Neighbouring this protected forest landscape is a transition zone where most settlement and infrastructure is found. This area is dominated by residential areas, infrastructure and service industries. East of the main settlements is the IJssel river, with adjoining floodplains and the traditional riverine landscape. Most land here is privately owned and used for agriculture.

Key developments in the region are an increasing pressure from urbanities and tourism on the traditional land use lay-out. Like elsewhere in the Netherlands, the municipality has been subject to processes of rationalization and intensification of agriculture during the 20th century resulting in disappearance of hedgerows and shrubs, land consolidation of traditional fine-mazed agricultural parcels, scaling-up of farm activities and reclamation of floodplains. Partly this intensification is still in progress as the number of farms has decreased. The average farm size has increased as fewer farms are now cultivating an agricultural area that has subsided only slightly. Organic farming is expected to increasing in coming years as a response to environmental and societal pressure. Furthermore, flood plains have been acknowledged by decision-makers as an important necessity for water retention and climate-proofing of the region.

The LGN Land cover maps were compared, a land cover map based on a combination of satellite imagery and farming statistics. We calculate the change in land use based on LGN3 and LGN5, since for LGN6 the classification was done in a slightly different way, which would result in changes due to the method used. All agricultural crops were clustered, to identify major tendencies in crop land use changes (Table 15).

Most striking is the decline in grassland (-2.6%), and a slight increase in crops (+1.2%). Otherwise there is limited change in land use: this probably has to do with the shorter time frame. For that reason we compared the historical land use maps (Knol et al., 2004). In the period 1970-1990 we observe an increase of cropland (2.5%), and a decrease in meadows (-2.3%). The large changes occurred at the first half of the 20th century, in particular a decrease of heathers and moors, which were planted with forests for production of timber for the mines, but also as reclamation of 'useless' commons. Natural areas were converted into farmland, and cropland gave way to grassland and built-up areas.

Table 15: Summary of land cover change, LGN 1996 till 2008

	LGN-3 (ha)		LGN-4 (ha)		LGN-5 (ha)		LGN-6 (ha)		Rel. Change LGN3-LGN	Absol. Change LGN3-LGN5
Grassland	3485	43%	3433	43%	3275	41%	3203	40%	-2.6%	-6.0%
Crops	507	6%	521	6%	601	7%	533	7%	1.2%	18.5%
Greenhouse	9	0%	9	0%	11	0%	11	0%	0.0%	22.2%
Orchard	33	0%	49	1%	63	1%	113	1%	0.4%	90.9%
Forest	2492	31%	2506	31%	2500	31%	2479	31%	0.1%	0.3%
Built-up area	635	8%	642	8%	684	9%	619	8%	0.6%	7.7%
Roads and railways	152	2%	152	2%	152	2%	142	2%	0.0%	0.0%
Natural vegetation	585	7%	585	7%	611	8%	742	9%	0.3%	4.4%
Wetland							35	0%	0.0%	
Water	137	2%	138	2%	138	2%	157	2%	0.0%	0.7%
SUM	8035		8035		8035		8034			

Table 16: Change in land cover, based on HGN maps for Heerde

Land use	1900 (ha)	%	1960 (ha)	%	1970 (ha)	%	1980 (ha)	%	1990 (ha)		Relative change, 1970-1990	Absolute change, 1970-1990
Meadow, grassland	2787	35%	3181	40%	3612	45%	3616	45%	3425	43%	-2.3%	-5.3%
Cropland	1564	19%	1156	14%	499	6%	579	7%	702	9%	2.5%	24.6%
Heathers and moors	2111	26%	654	8%	576	7%	579	7%	613	8%	0.5%	0.0%
Forest	1316	16%	2425	30%	2573	32%	2558	32%	2557	32%	-0.2%	0.0%
Infrastructure and roads	202	3%	423	5%	495	6%	352	4%	465	6%	-0.4%	22.8%
River, stream	55	1%	104	1%	88	1%	130	2%	141	2%	0.7%	12.5%
Marshland			7	0%	5	0%	5	0%	8	0%	0.0%	60.0%
Sand dunes			6	0%	10	0%	14	0%	5	0%	-0.1%	-90.0%
Built-up area			76	1%	167	2%	192	2%	107	1%	-0.7%	-50.9%
Hothouses			3	0%	10	0%	10	0%	12	0%	0.0%	20.0%
SUM	8035		8035		8035		8035		8035			

Relatively small changes from 1900 until 1990 (Table 16): the productive area decreased by only 2%, mostly a decline of cropland with a small increase in grassland. The non-productive areas increased, mostly heathers that were converted into forest (for mining industry) at the beginning of the 20th century, and an increase in housing and other infrastructure.

The Global land cover data show a decrease in closed/open grassland (-13%), and sparse vegetation (-5%). At the same time, there is an increase of closed mosaic of grass and forest (+9%), closed broadleaved forest (+7%) and mixed forest (+6%). This may illustrate the process of more residential use of farming areas, with more planting of trees, and expansion of gardens at the detriment of the open meadow landscape.

Table 17: Global land cover for Heerde area, for the period of 2005 to 2009

CODE	LAND COVER	2006 (ha)	%	2009 (ha)	%	Rel. change, 2005-2009	Abs. change, 2005-2009
14	Rainfed crop	397	5%	135	2%	-3.3%	-66.0%
20	Mosaic Crop/vegetation	443	6%	112	1%	-4.1%	-74.7%
30	Mosaic veget./Crop			113	1%	1.4%	
50	Closed BroadLfd forest	994	12%	1570	20%	7.2%	57.9%
70	Closed Evergreen forest	109	1%	215	3%	1.3%	97.2%
90	Open forest	333	4%	21	0%	-3.9%	-93.7%
100	Closed/open forest	1997	25%	2464	31%	5.8%	23.4%
110	Mosaic Forest/grass	409	5%	762	9%	4.4%	86.3%
120	Mosaic Grass/Forest	42	1%	759	9%	8.9%	1707.1%
140	Closed/Open Grass	2770	34%	1728	22%	-13.0%	-37.6%
150	Sparse Vegetation	381	5%			-5%	-100%
190	Artificial surface	122	2%	121	2%	0%	-1%
210	Water	38	0%	35	0%	0%	-8%
SUM		8035		8035			

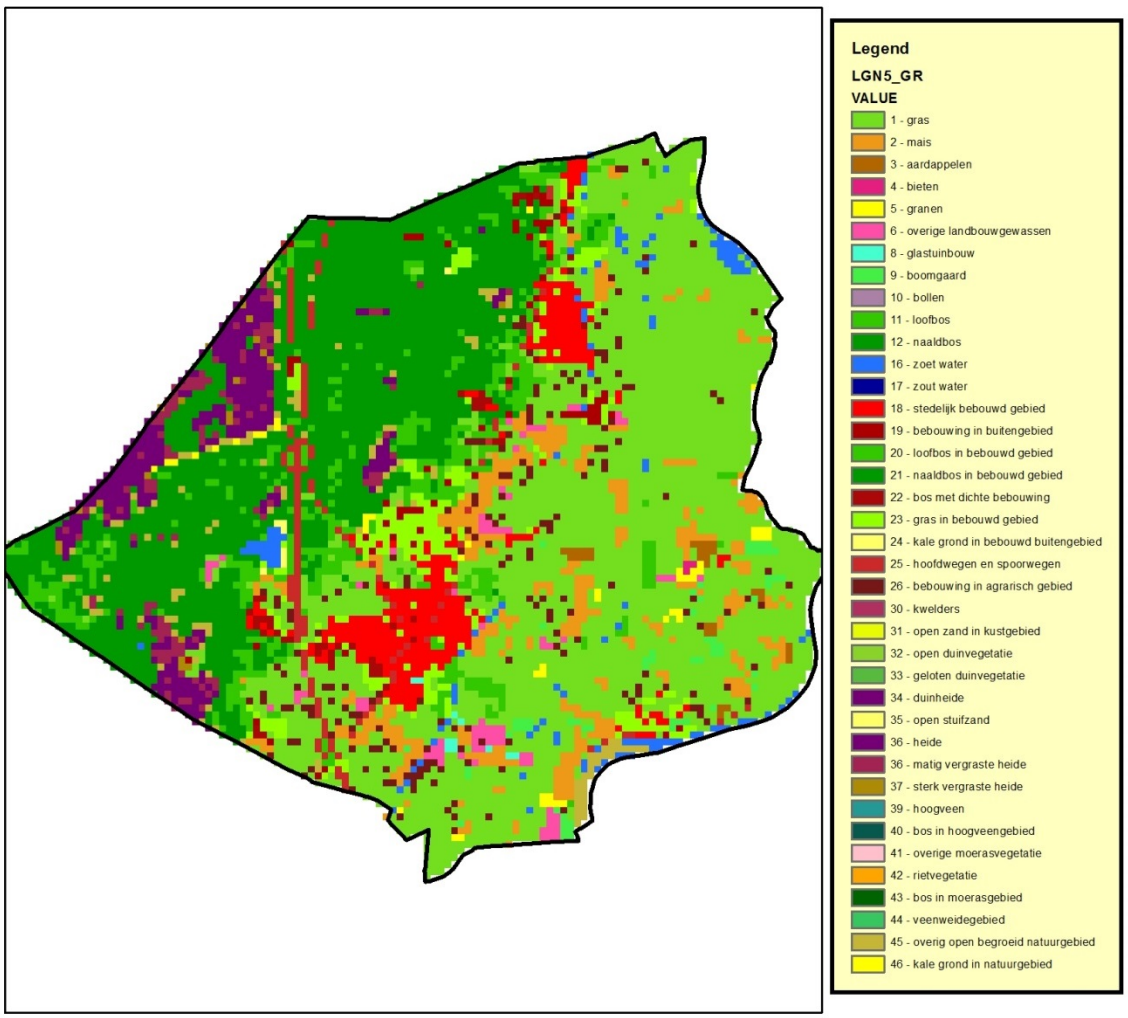

Figure 14: Land cover 2003-2004 (LGN-5) for Heerde

Some 9% of change occurred between 1995 and 2004, some 91% was stable. Changes occur in all areas west of the Veluwe, outside the Natura2000 area, in particular around the settlements and along the road (running roughly NE-SW), and in the large scale farming zone along the river, in the south-east. Changes are very diverse, but mostly towards grassland or crops. Expansion of built-up area is not so apparent.

Portofino

Portofino is located in the Mediterranean north region. The area is the smallest of all case study areas, and measures some 18 km2. The peninsula is an iconic Mediterranean landscape on the Italian Riviera, with steep rock cliffs over the Tyrrhenian Sea on the south side and deciduous forests on the north. On the east slopes small scale terraced agriculture has transformed in gardens for semi-residential housing, at the foot slopes culminating in the famous picturesque small natural harbour of Portofino. Since the peninsula was declared a nature reserve in the 1930s, it was protected to a considerable extent from mass tourist exploitation. However, the current Regional Park of the Monte di Portofino is subject to strong pressures of tourism and urban areas, and is at risk of substantial loss of its traditional values of outstanding natural beauty and cultural heritage. This problem is emblematic for large parts of the Mediterranean, and asks for a comprehensive approach to land use management.

Table 18: Change in land cover, based on vegetation maps for Portofino (Pedroli et al., 2013)

Description	1936 (ha)	%	1954 (ha)	%	1974 (ha)	%	2000 (ha)	%	Rel. change, '74-2000	Abs. change, '74-2000
Agricultural land	571.8	31%	565.9	31%	488.9	26%	398.5	22%	-4.9%	-18.5%
Meadow, grassland	5.1	0%	5.2	0%	21.2	1%	6.9	0%	-0.8%	-67.6%
Abandoned	0.0	0%	0.0	0%	33.1	2%	100.2	5%	3.6%	202.5%
Forest	901.4	49%	955.4	52%	966.1	52%	983.2	53%	0.9%	1.8%
Macchia	277.2	15%	237.6	13%	257.7	14%	255.9	14%	-0.1%	-0.7%
Open vegetation or bare	47.3	3%	49.6	3%	48.3	3%	47.0	3%	-0.1%	-2.7%
Reforestation	15.9	1%	0.0	0%						
Forest harvesting	8.0	0%	9.8	1%						
New coastal area	0.3	0%	0.3	0%	0.1	0%			0.0%	-100.0%
River, stream	0.2	0%	0.2	0%	0.2	0%	0.2	0%	0.0%	43.9%
Power line	0.0	0%	0.0	0%	1.4	0%	4.0	0%	0.1%	181.8%
Built-up area	12.1	1%	15.8	1%	20.0	1%	35.9	2%	0.9%	79.6%
Area of public interest	5.7	0%	5.3	0%	7.9	0%	13.1	1%	0.3%	67.1%
TOTAL	1844.9		1844.9		1845.0		1845.0			

If we compare the totals for land use from the year 1974 to 2000, which is relevant for our comparison, we observe a decrease of agricultural land by 91 ha (-4.9%, calculated towards total land use), and an increase in abandoned land which doubled (+3.6%) and a slight increase in built-up areas (+0.9%) (Table 18).

The decline of farming is the most dominant process, it is the trend over most of the past century to date. The classification of agriculture was not always consistent (Table 19), for 1954 no olive yards were registered, but, since it is a perennial crop, it is likely that this was included in 'agricultural land' (not specified). In 2000 also arable and horticulture as well as grapes were included, which were not included in the previous years. Overall, agricultural land has reduced significantly with less than 400 ha. nowadays.

Table 19: Decline of agricultural land use in Portofino

Description	1936 (ha)	1954 (ha)	1974 (ha)	2000 (ha)
Agricultural land	157	566	113	
Arable and horticulture				17
Grapes				2
Olive yard	415		376	293
Complex cultivated areas				86
Total	572	566	489	398

The Global land cover data is less suitable for this analysis, since Portofino is one of the smaller areas, and the results are therefore much influenced by the grid cell size. One cell in GLC measures some 6 ha, which means that all of Portofino is some 30 grid cells. Relative small changes are quite considerable when expressed as %.

We observe for Global land cover a large increase of closed to open mixed broadleaved and needle-leaved forest (+21%), mostly at the expense of closed broadleaved deciduous forest (-25%). This increase occurs mostly on south-southwest exposed slopes, and can be a result of e.g. forest fire(s), which opened up the forest. The increase in mosaic vegetation/crops (+8%) occurs mostly in the north of the study area.

Table 20: Global land cover for Portofino area, for the period of 2005 to 2009

CODE	LAND COVER	2006 (ha)	%	2009 (ha)	%	Rel. change, 2005-2009	Abs. change, 2005-2009
14	Rainfed crop			36.24	2%	2.0%	
20	Mosaic Crop/vegetation	40.68	2%	53.67	3%	0.7%	31.9%
30	Mosaic veget./Crop			149.2	8%	8.1%	
50	Closed BroadLfd forest	1362.36	74%	908.33	49%	-24.6%	-33.3%
70	Closed Evergreen forest	285.27	15%	207.25	11%	-4.2%	-27.3%
100	Closed/open forest	21.23	1%	416.28	23%	21.4%	1860.8%
130	Closed/Open Shrub land	24.55	1%	13.05	1%	-0.6%	-46.8%
150	Sparse Vegetation	43.94	2%			-2.4%	-100.0%
190	Artificial surface	4.47	0%	4.58	0%	0.0%	2.5%
210	Water	62.62	3%	56.52	3%	-0.3%	-9.7%
SUM		1845.12		1845.12			

If we compare productive area (Table 21) we observe a decline by -9% (even with 'open area' included, which can be gardens, but also open, rocky natural areas). This can mostly be attributed to change in total forest and macchia.

We observe a lot of changes for Portofino: more than half of the territory changed. A large proportion of change has to do with the change from e.g. macchia (shrubland) towards forest, but the large territory that changed in the western part of the area was also 'open', grassland in 1974, and is now mostly covered. North of Portofino olive yards have expanded much as well.

Table 21: Long term land cover data (1936-2000) (ha) for Portofino, based on classified aerial photography (Pedroli et al., 2013)

Description	1936	1954	1974	2000	change 1936-2000
Agricultural land	572	566	489	398	
Meadow, grassland	5	5	21	7	
Open vegetation or bare	47	50	48	47	
Productive	624	621	558	452	-9%
Abandoned	0	-	33	100	
Forest & macchia	1203	1203	1224	1239	
Infrastructure & housing	18	21	29	53	
Non-productive	1221	1224	1287	1393	9%
Sum	1845	1845	1845	1845	

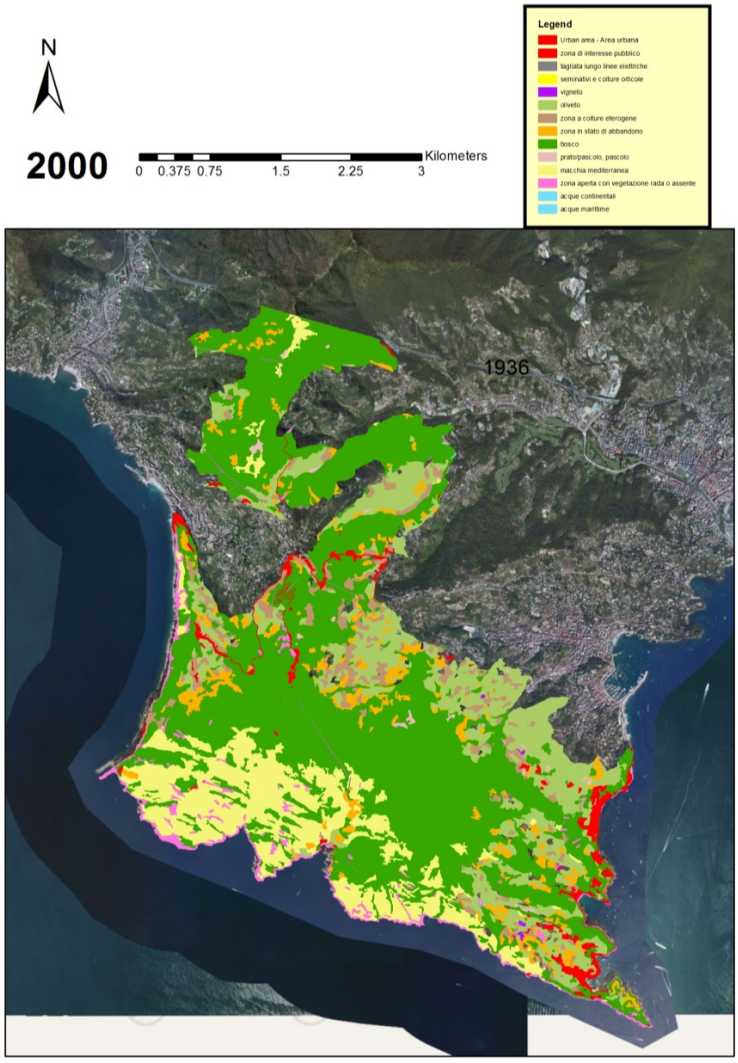

Figure 15: Land cover map Portofino, 2000

The Portofino landscape changed much over time with the abandonment of farmland on the Southern slopes. However, many terraces (and stone walls) are also found on the forested slopes in the North. Except for olive groves, also many Chestnut groves are found there. Management of these groves was abandoned around the World War II, and so was the maintenance of these terraces and stone walls. As a result many of these terraces are nowadays in decline (Figure 16).

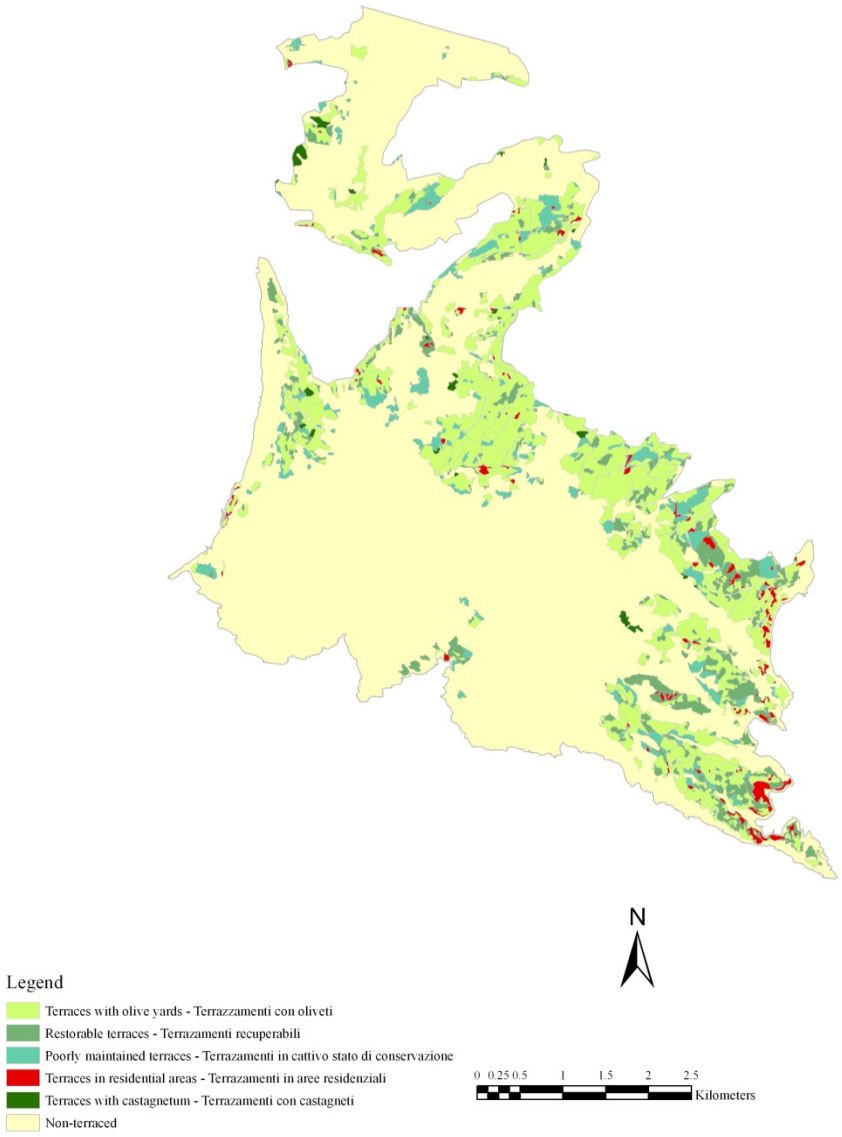

Figure 16: detailed map of the Portofino terraces and their state of maintenance (Pedroli et al. 2013)

Stăncuţa and Răteşti

Romania has two case study areas: Stăncuţa and Răteşti municipalities, representative of the rural South-East part of Romania. Stăncuţa is situated in the Danube floodplains and measuring some 255 km2, the other area, Răteşti, is situated in the south part of Arges county, in the Romanian plain and measures some 79 km2.

A common denominator for land use (change) in the two areas is the history of the landscape. The agricultural policies in the Romanian Socialist Republic before 1989 were focused on gaining more land for crop production by conversion of natural and semi-natural areas into mono-functional agro-ecosystems (Vadineanu, 2004). After the revolution in 1989 this changed.

Răteşti

Răteşti municipality is an administration consisting of 7 villages, with a population of 3300 people. Land is use is predominantly agricultural, with almost 80% of the area used for cereal and vegetable crops (Table 23). There are still some cultivated pastures for small animal production, but over the years the stocking rate decreased (Table 22). Forest cover is about 8% of the area.

Table 22: Livestock in Răteşti

Livestock	1990	1995	2000	2002	2005	2010
Cattle	4267	3452	1887	1840	1536	2244
Pigs	7475	1031	1750	1500	3150	1559
Sheeps	2907	2481	1795	2489	2733	2286

Source: Ministry of Agriculture, Bulgaria

Table 23: Change in land cover, based on land use maps Răteşti

Land cover	1980 (ha)	%	2003 (ha)	%	2013 (ha)	%	Rel. change, 1980-2013	Abs. change, 1980-2013
Arable land	6102	77%	6445	82%	5,806	76%	-3.8%	-2.2%
Meadows and pastures	713	9%	143	2%	507	7%	-2.7%	-26.9%
Orchards	75	1%	2	0%	12	0%	-0.8%	-83.9%
Vineyard	5	0%					-0.1%	-100.0%
Forest, shrubs	487	6%	648	8%	595	8%	1.4%	25.5%
Natural vegetation, wetland, grassland	153	2%	26	0%	67	1%	-1.1%	-54.6%
Water	39	0%	133	2%	167	2%	1.7%	304.9%
Infrastructure & housing	330	4%	507	6%	532	7%	2.6%	67.7%
Sum	7904		7904					

An increase of built-up areas (+2.6) and forest (+1.4%) on the account of cropland (-3.8%) and meadows and pastures (-2.7%). Statistical data showed that the 570 hectares of pastures were transformed in 2001-2002.

The changes of land cover are not that large, considering the long period of 33 years, and the enormous political changes that took place in the area. The changes occurred mainly in the structure and management of the agricultural ecosystems due to the change of ownership of the land after 1990, when large state owned farms were replaced by small subsistence farms. Fragmentation of agricultural land increase by 2005 (Kuemmerle et al. 2009), but this had no measurable effect on land abandonment in the lowlands of Arges (Müller et al. 2009). Since the beginning of 1990 the area of forest vegetation increased by 108 hectares. In 2009 a mineral aggregate holding (ballast) was established over an area of 370 ha on the Arges river shore.

Table 24: Crops and total production in Răteşti

Crops	1990		1995		2000		2005		2010	
	area (hectares)	yields (tons)	area (hectares)	yields (tons)	area (hectares)	yields (tons)	area (hectares)	yields (tons)	area (hectares)	yields (tons)
wheat	1640	8288	2000	7662	960	1556	1880	5640	1600	4000
barley	*	*	*	*	*	*	570	1610	200	490
oatmeal	*	*	*	*	*	*	500	800	*	*
corn	1269	4356	1382	3879	1337	3100	1000	3600	1200	4300
sunflower	60	72	*		80	23	100	130	80	136
rape	*	*	60	0			100	140	160	256
potatoes	85	272	30	210	50	350	60	640	50	780
vegetables	156	1745	40	280	85	735	196	2530	195	1965
***No data**										

Source: Ministry of Agriculture

Only limited changes are observed for Global Land cover: sparse vegetation decreases (-7%) towards mosaic vegetation and crops (+4%). It seems therefore that abandoned land is cultivated again.

Table 25: Global land cover for Răteşti area, for the period of 2005 to 2009

CODE	LAND COVER	2006 (ha)	%	2009 (ha)	%	Rel. change, 2005-2009	Abs. change, 2005-2009
14	Rainfed crop	3486	44%	3596	46%	1.4%	3.1%
20	Mosaic Crop/vegetation	3490	44%	3564	45%	0.9%	2.1%
30	Mosaic veget./Crop	0	0%	279	4%	3.5%	
50	Closed BroadLfd forest	358	5%	329	4%	-0.4%	-8.0%
110	Mosaic Forest/grass	33	0%			-0.4%	-100.0%
120	Mosaic Grass/Forest			132	2%	1.7%	
150	Sparse Vegetation	532	7%			-6.7%	-100.0%
SUM		7899		7899			

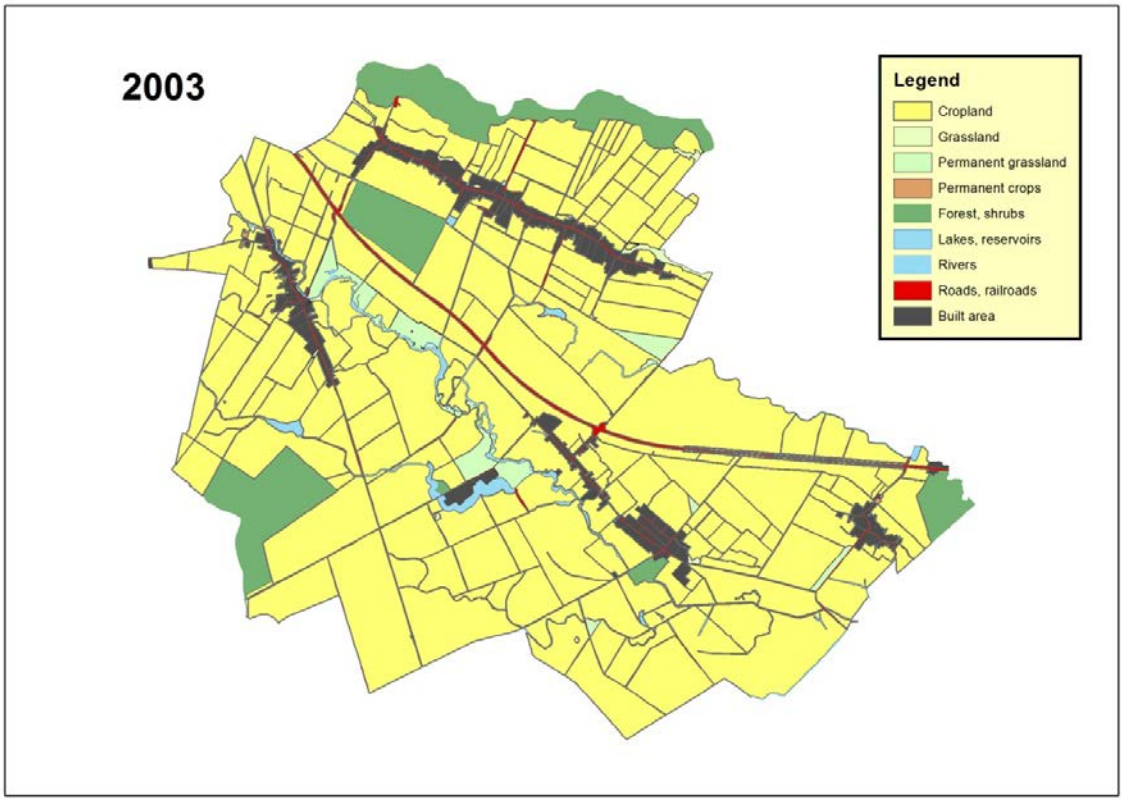

Figure 17: Land cover map Răteşti, 2003

In Răteşti productive land decreased by -4% for the period of 1980-2003 (Table 23), whereby orchards and grassland decreased almost entirely. The forest and housing and infrastructure increased.

Table 26: Long term land cover data (1980-2003) (ha) for Răteşti (RO), based on classified satellite imagery

Land cover	1980	2003	Change
Arable land	6102	6445	
Orchards	75	2	
Meadows and pastures	713	143	
Vineyard	5	0	
Productive	6895	6591	-4%
Forest, shrubs	487	648	
Natural vegetation	153	26	
Water	39	133	
Infrastructure & housing	330	507	
Non-productive	1009	1313	4%
Sum	7904	7904	

The total change observed between 1980 and 2003 was some 13%, so 87% remained stable over this period. Most change involved change into cropland, which involved large extended fields, mostly along the river from NW-to SE. Some forest was planted, and a limited expansion of grassland took place. Almost no change towards built-up area.

An assessment was done of change in landscape elements. Based on the maps, and a field check, the following was found....

Landscape element	2003	2013	Change
trees	360	-	
shrubs	870	-	
treeline: N	122	-	
Sum	16237	-	
Avg. length	133	-	

Stăncuţa

There is an increase in rivers (+2.7%), which can be explained by the overrepresentation of Danube River due to high water level at the time of acquisition of the aerial photos. Meadows and pastures decreased by -1.8%).

Table 27: Change in land cover, based on land use maps Stăncuţa

Land cover	1980 (ha)	%	2003 (ha)	%	Rel. change, 1980-2003	Abs. change, 1980-2003
Arable land	13376	52%	13058	51%	-1.2%	0.0%
Orchards	12	0%			0.0%	-100.0%
Meadows	874	3%	401	2%	-1.8%	-54.3%
Vineyards	90	0%			-0.4%	-100.0%
Forest, shrubs	7712	30%	8081	31%	1.4%	4.3%
Natural	224	1%	2	0%	-0.9%	-99.2%
Lakes & reservoirs	28	0%			-0.1%	-100.0%
Rivers	2774	11%	3462	13%	2.7%	24.3%
Infrastructure & housing	482	2%	676	3%	0.8%	39.9%
	25573		25680			

We observe changes for Global land cover data in particular in areas with Mosaic vegetation/crops (+12%) towards sparse vegetation (-15%). This may be a result of map interpretation (or classification). However, this could also be a result of reclamation of formerly abandoned (or not cultivated) land.

We compared total productive land for the period of 1980-2003, during which productive land decreased from 57 to 43.5% as a result of an increase of forest area and river (…). Also housing and infrastructure increased in this period.

Table 28: Global land cover for Stăncuţa area, for the period of 2005 to 2009

CODE	LAND COVER	2006 (ha)	%	2009 (ha)	%	Rel. change, 2005-2009	Abs. change, 2005-2009
14	Rainfed crop	7128	28%	7711.06	30%	2.3%	8.2%
20	Mosaic Crop/vegetation	6091	24%	9069	35%	11.6%	48.9%
30	Mosaic veget./Crop			824.8	3%	3.2%	
50	Closed BroadLfd forest	4	0%	466.77	2%	1.8%	12347.2%
70	Closed Evergreen forest	281	1%	135.8	1%	-0.6%	-51.6%
90	Open forest	347	1%	26	0%	-1.3%	-92.5%
140	Closed/Open Grass			47.88	0%	0.2%	
150	Sparse Vegetation	3991	16%	79.42	0%	-15.3%	-98.0%
180	Grassland on regularly flooded area	4601	18%	4288.95	17%	-1.2%	-6.8%
190	Artificial surface	39	0%			-0.2%	-100.0%
210	Water	3116	12%	2947.85	12%	-0.7%	-5.4%
SUM		25598		25598			

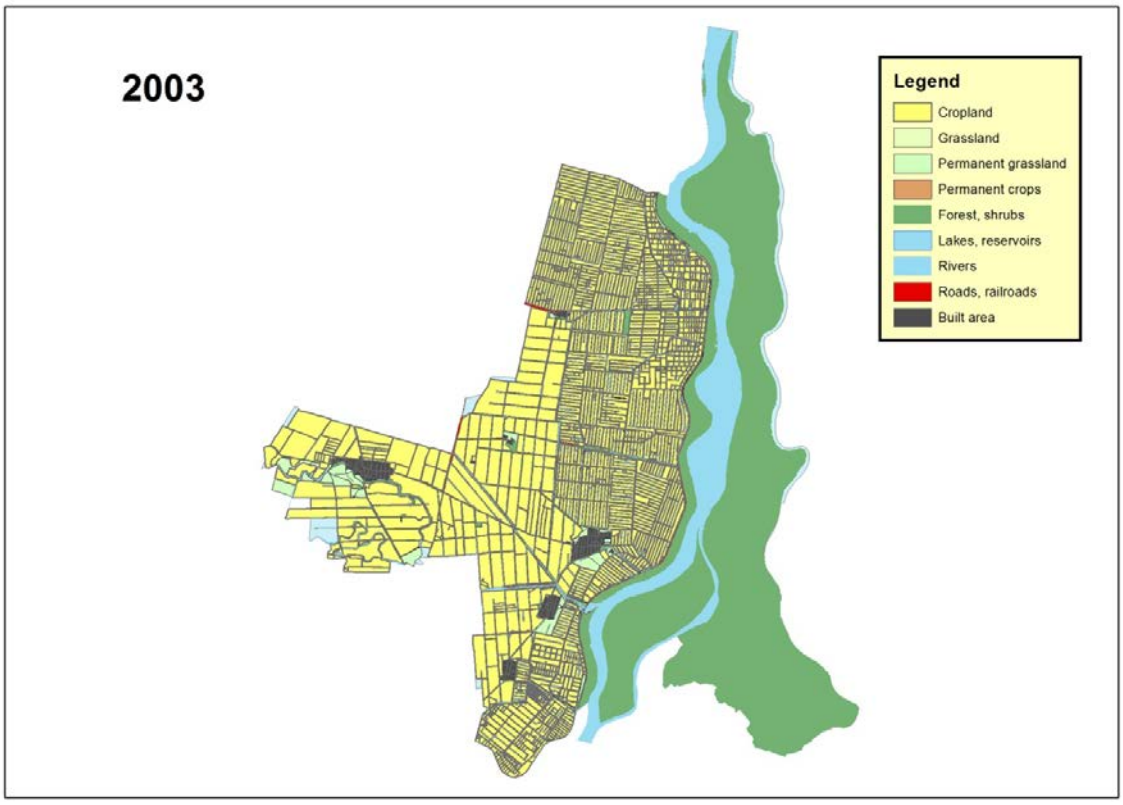

Figure 18: Land cover map Stăncuţa , 2003

If we look at where land use change occurs, we see that it is not all over the area, but changes seem to occur mostly near settlements in the centre and west (Figure 10). In total 11% of the land use changed between 1980 and 2003, while 89% was stable. Also here it is some large arable fields that were established, and along the Danube river some forests and few grasslands in the west.

The number of trees and shrubs almost is the same over the observed decade. However, the number and length of treelines changed very significantly, some treelines disappeared apparently.

Landscape element	2003	2013	Change
trees	74	76	2
shrubs	229	241	12
treeline: N	40	25	-15
Sum	14760	8329	-6431
Avg. length	369	333	-36

Annex 2: Landscape indices for the case study areas calculated with FRAGSTATS

The following indicators have been calculated with Fragstats (Mcgarigal et al., 2002):

- TA=Total area
- NP=Number of Patches
- PD=Patch density
- TE=Total edge
- ED=Edge density
- AREA_MN=Patch area (mean)
- PARA_MN= Shape Perimeter-area ration (Mean)
- CONTAG = Contagion (aggregation)
- SHDI=Shannons' Diversity Index
- SHEI=Shannons Evenness Index

Table 29: Landscape indices for Lesvos (Fragstats, based on Land Cover data). Colours indicate small decrease, large decrease, small increase, large increase

LID	TA	NP	PD	TE	ED	AREA_MN	PARA_MN	CONTAG	SHDI	SHEI
D:\GIS\VOLANTE\Lesvos\LandUse60_GR1.tif	10422.80	144	1.3816	306360	29.3933	72.3806	451.5763	65.505	1.3411	0.6449
D:\GIS\VOLANTE\Lesvos\LandUse04_GR1.tif	10398.79	197	1.8945	382220	36.7562	52.7857	391.3206	65.8911	1.4555	0.6321

Table 30: Landscape indices for Reichraming (Fragstats, based on Global Land Cover data). Colours indicate small decrease, large decrease, small increase, large increase

LID	TA	NP	PD	TE	ED	AREA_MN	PARA_MN	CONTAG	SHDI	SHEI
D:\GIS\VOLANTE\Reichraming\globcov05_gr1.tif	10263	154	1.5005	278450	27.1314	66.6429	257.3635	63.5541	1.6593	0.692
D:\GIS\VOLANTE\Reichraming\globcov09_gr1.tif	10263	208	2.0267	337290	32.8647	49.3413	282.0889	63.3862	1.5823	0.6872

Table 31: Landscape indices for Roskilde (Fragstats, based on Land Use/ Land Cover data). Colours indicate small decrease, large decrease, small increase, large increase

LID	TA	NP	PD	TE	ED	AREA_MN	PARA_MN	CONTAG	SHDI	SHEI
D:\GIS\VOLANTE\Roskilde\CLUC\Lu_1990GR1.tif	21225.94	3198	15.0665	1334375	62.8653	6.6373	1041.518	63.9758	1.0522	0.5407
D:\GIS\VOLANTE\Roskilde\CLUC\Lu_2011GR2.tif	21225.94	3131	14.7508	1390175	65.4942	6.7793	987.115	62.1624	1.107	0.5689

Table 32: Landscape indices for Heerde (Fragstats, based on LGN data). Colours indicate small decrease, large decrease, small increase, large increase

LID	TA	NP	PD	TE	ED	AREA_MN	PARA_MN	CONTAG	SHDI	SHEI
D:\GIS\VOLANTE\Heerde\LGN3plus_GR1.tif	8035	780	9.7075	505600	62.9247	10.3013	338.0055	52.1269	1.9998	0.6213
D:\GIS\VOLANTE\Heerde\LGN5_GR1.tif	8035	844	10.504	527300	65.6254	9.5201	338.4681	49.5515	2.0955	0.651

Table 33: Landscape indices for Portofino (Fragstats, based on Portofino Land Cover data). Colours indicate small decrease, large decrease, small increase, large increase

LID	TA	NP	PD	TE	ED	AREA_MN	PARA_MN	CONTAG	SHDI	SHEI
D:\GIS\VOLANTE\Portofino\Ussd36a1_GR1.tif	1844.83	348	18.8635	224640	121.7673	5.3012	1058.419	65.6576	1.4082	0.5667
D:\GIS\VOLANTE\Portofino\Ussd001a1_GR1.tif	1844.87	976	52.9035	371980	201.6294	1.8902	1585.079	61.7907	1.4933	0.5822

Table 34: Landscape indices for Răteşti (Fragstats, based on Răteşti Land use maps). Colours indicate small decrease, large decrease, small increase, large increase

LID	TA	NP	PD	TE	ED	AREA_MN	PARA_MN	CONTAG	SHDI	SHEI
D:\GIS\VOLANTE\Roemenie\rates_ag80gr1.tif	7898.88	246	3.1144	381930	48.3524	32.1093	877.8563	77.5563	0.9055	0.3933
D:\GIS\VOLANTE\Roemenie\Rates_agr03GR1.tif	7899.29	2628	33.2688	658950	83.4189	3.0058	3467.42	77.8862	0.7944	0.3616

Table 35: Landscape indices for Stăncuţa (Fragstats, based on Stăncuţa Land use maps). Colours indicate small decrease, large decrease, small increase, large increase

LID	TA	NP	PD	TE	ED	AREA_MN	PARA_MN	CONTAG	SHDI	SHEI
D:\GIS\VOLANTE\Roemenie\Stanc_80_GR1.tif	25572.54	1539	6.0182	1678565	65.6394	16.6157	1427.1142	64.5334	5.0215	0.6967
D:\GIS\VOLANTE\Roemenie\Stanc_03_GR1.tif	25641.33	6141	23.9496	3071370	119.782	4.1754	2957.0482	65.4082	5.5805	0.6751

Annex 3: Land conversion tables

The tables below show how land cover changed over time. For example, one can see that olive groves were 53,899,700 ha. in 1981, and in 2004 some 1,811,833 ha. changed into 'build-up area', i.e. olive groves were converted in housing area (see yellow-highlighted number at cross-line olives and build-up). Marshland remained the same for both years, i.e. 390,231 ha. All tables below should be read this way.

Table 36: Lesvos land conversion, comparison 1981 (rows) with 2004 (columns) (ha)

	airport	bare ground	brush	build up	coniferous forest	crops	grassland	marsh	not classified	olive groves	sparsely coniferous forest	SUM
airport	23	-	-	-	-	-	-	-	-	-	-	23
bare ground	-	148	-	-	-	-	-	-	-	-	-	148
brush	-	2	811	1	-	-	1	-	-	0	-	815
build up	-	-	0	418	-	-	0	-	-	6	-	424
coniferous forest	-	-	-	8	2,690	-	0	-	2	0	-	2,701
crops	-	-	-	27	-	437	-	-	0	0	1	466
grassland	-	0	-	3	-	-	564	-	15	0	-	582
marsh	-	-	-	-	-	-	-	39	-	-	-	39
not classified	-	-	-	3	-	1	1	-	59	2	0	66
olive groves	-	-	0	181	31	18	3	-	1	5,156	-	5,390
sparsely coniferous forest	-	-	-	-	-	-	-	-	-	-	201	201
(blank)	-	-	-	7	0	-	1	-	-	2	-	10
SUM	23	150	812	648	2,721	456	570	39	77	5,167	201	10,865

Table 37: Reichraming land conversion, comparison GLC 2005 (rows) with GLC 2009 (columns) (ha)

	Crops	Mosaic crops/vegetation	Mosaic veg/crops	Closed broadleaved decid. Forest	Closed needle lvd. Forest	Open needle lvd. Forest	Closed to open mixed broadlvd. Forest	Mosaic forest-shrubland/grassland	Mosaic grassland/forest-shrubland	Closed to open grassland	Sparse vegetation	Artificial area	SUM
Crops	6,49	-	-	26,41	-	-	6,37	-	-	-			39,27
Mosaic crops/vegetation	-	49,81	-	31,79	-	-	6,45	-	-	-			88,05
Mosaic veg/crops													-
Closed broadleaved decid. Forest	-	96,83	213,04	2183,56	58,31	-	519,94	-	20,87	-			3192,55
Closed needle lvd. Forest	-	351,72	61,28	-	223,55	-	396,25	-	-	-			2032,80
Open needle lvd. Forest	-	6,39	-	-	89,98	0,11	83,29	-	-	-			179,77
Closed to open, mixed broadlvd. Forest	-	159,98	175,02	-	524,76	-	2293,66	-	6,34	-			3159,76
Mosaic forest-shrubland/grassland	6,51	9,05	25,85	89,69	6,36	-	44,96	96,26	51,40	50,98			381,06
Mosaic grassland/forest-shrubland	-	32,19	126,65	472,87	-	-	-	6,51	83,61	6,51			728,34
Closed to open grassland	-	-	25,84	89,49	-	-	-	12,83	6,30	-			134,46
Sparse vegetation	-	-	38,60	218,44	6,33	-	6,51	-	12,52	38,17			320,57
Artificial area	-	-	-	6,37	-	-	-	-	-	-			6,37
SUM	13,00	705,97	666,28	3118,62	2009,29	0,11	3357,43	115,60	181,04	95,66	-	-	

Table 38: Roskilde land conversion, comparison of 1990 (rows) with 2011 (columns) (ha)

	Settlement	Lake	Forest	Grassland	Wetland	Cropland	Sea	SUM
Settlement	4822.5	-	-	-	-	-	-	4822.5
Lake	0.0	282.4	-	-	-	-	-	282.4
Forest	0.3	1.3	707.1	3.6	6.1	4.2	-	722.5
Grassland	-	-	-	1237.5		171.8	-	1409.3
Wetland	0.2	-	-	-	399.4		-	399.6
Cropland	384.6	14.4	332.8	-	68.0	12783.3	-	13583.1
Sea	-	-	-	-	-	-	6.6	6.6
SUM	5207.6	298.1	1039.8	1241.1	473.4	12959.3	6.6	

Table 39: Heerde land conversion, comparison LGN-3, 1995 (rows) with LGN-5, 2004 (columns) (ha)

	Grass	Maize	Horticul-ture	Orchards	Crops	Deciduous forest	Pine forest	Water	Built-up area	Forest w. residences	Bare terrain	Infra-structure	Nature	SUM LGN-5
Grass	3087	201	2	21	79	13	-	1	50	-	-	-	31	3485
Maize	138	236	-	5	42	-	-	-	2	-	-	-	-	423
Horticulture	-	-	9	-	-	-	-	-	-	-	-	-	-	9
Orchards	2	3	-	28	-	-	-	-	-	-	-	-	-	33
Crops	35	-	-	8	40	-	-	-	1	-	-	-	-	84
Deciduous forest	-	-	-	-	-	514	-	-	4	-	-	-	-	518
Pine forest	-	-	-	-	-	1	1972	-	1	-	-	-	-	1974
Water	-	-	-	-	-	-	-	137	-	-	-	-	-	137
Built-up area	8	-	-	1	-	-	-	-	561	-	-	-	-	570
Forest with residences	-	-	-	-	-	-	-	-	3	54	-	-	-	57
Bare terrain	-	-	-	-	-	-	-	-	-	-	8	-	-	8
Infrastructure	-	-	-	-	-	-	-	-	-	-	-	152	-	152
Natural area	5	-	-	-	-	-	-	-	-	-	-	-	580	585
SUM LGN-3	3275	440	11	63	161	528	1972	138	622	54	8	152	611	

Table 40: Portofino land use change, comparison 1980 (rows) with 2000 (columns) (ha)

	Built-up area	public area	Power lines	Agricultural area	Horticulture	Vineyards	Olive yard	Abandoned	Forest	Grassland	Macchia	Sparse vegetation	SUM
Built-up area	15.10	-	5.70	-	-	0.32	0.06	-	0.12	-	0.14	-	21.44
public area	0.08	3.05	-	-	-	0.03	-	-	0.20	-	-	-	3.36
Power lines	-	-	0.13	-	-	-	-	-	0.11	0.05	-	-	0.29
Agricultural area	3.05	0.07	3.46	-	11.22	45.55	29.45	4.63	9.00	0.67	0.73	-	107.81
Horticulture	-	-	-	-	-	-	-	-	-	-	-	-	-
Vineyards	-	-	-	-	-	-	-	-	-	-	-	-	-
Olive yard	2.86	0.06	3.58	-	7.46	32.65	302.76	6.90	14.61	2.29	0.23	-	373.40
Abandoned	-	-	0.08	-	1.53	1.54	15.98	5.76	4.17	1.70	-	-	30.75
Forest	2.64	0.61	5.12	-	2.90	2.43	17.24	0.94	900.88	43.17	3.08	0.08	979.10
Grassland	-	-	-	-	1.03	-	0.34	-	8.05	10.18	-	-	19.61
Macchia	-	-	-	-	-	0.09	0.06	0.07	55.96	206.38	0.56	-	263.12
Sparse vegetation	0.06	0.10	0.17	-	0.04	-	0.04	-	1.09	1.74	27.77	-	31.03
SUM	23.78	3.94	18.25	0.00	24.18	82.61	365.94	18.29	994.18	266.18	32.51	0.08	

Table 41: Răteşti land use change, comparison 1980 (rows) with 2003 (columns) (ha)

	Built-up area	Permanent crops	Infra-structure	Lakes	Grassland	Rivers	Forest, shrubs	Permanent Grassland	Cropland	Vineyards	SUM
Built-up area	189	0	4	0	0	1	-	-	16	-	211
Permanent crops	24	-	1	-	-	0	-	-	50	-	75
Infrastructure	7	0	90	0	0	1	-	-	21	-	119
Lakes	0	-	0	15	1	1	0	-	2	-	18
Grassland	8	-	1	4	5	15	102	5	13	-	153
Rivers	-	-	-	0	-	2	17	1	1	-	21
Forest, shrubs	3	-	0	-	0	0	473	-	10	-	487
Permanent Grassland	10	-	4	12	8	20	2	81	576	-	713
Cropland	121	2	44	16	11	47	54	56	5,751	-	6,102
Vineyards	-	-	0	0	-	-	-	-	5	-	5
SUM	362	2	145	46	26	87	648	143	6,445	0	7,904

Table 42: Stăncuţa land use change, comparison 1980 (rows) with 2003 (columns) (ha)

	Built area	Permanent crops	Infra-structure	Lakes	Grassland	Rivers	Forest, shrubs	Permanent Grassland	Cropland	Vineyard	(blank)	SUM
Built area	245	1	1	-	1	1	-	35	16	-	0	298
Permanent crops	-	-	-	-	-	-	-	-	-	-	-	-
Infrastructure	1	1	168	-	2	92	1	14	93	1	5	378
Lakes	-	-	-	-	-	-	-	-	-	-	-	-
Grassland	-	-	-	-	-	-	-	-	2	-	-	2
Rivers	-	-	33	3	20	2,356	345	45	555	0	105	3,462
Forest, shrubs	4	1	20	19	179	50	7,366	31	75	-	337	8,081
Permanent Grassland	0	7	0	-	11	6	-	275	95	-	7	401
Cropland	3	3	7	7	9	41	-	471	12,389	88	40	13,058
Vineyards	-	-	-	-	-	-	-	-	-	-	-	-
(blank)	-	-	0	-	2	229	-	3	151	-	-	386
SUM	252	12	229	28	224	2,774	7,712	874	13,376	90	494	26,066